THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. VI. 1880. No. XIII.

NAVAL INSTITUTE, ANNAPOLIS.

APRIL 8, 1880.

P. A. ENG. C. H. MANNING, U. S. N., in the Chair.

THE VALUATION OF COAL.

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MR. CHAIRMAN:—

By the valuation of coal is meant the estimation by experiment of its value as a calorific agent, and it will be admitted that the discovery of some method which will readily give accurate and reliable results, and which will enable us to avoid the costly and prolonged test of actual use—a test which may involve great waste and prove very vexatious—is a great desideratum.

In valuing a coal the estimation of the calorific power is of the first importance, yet there are other characteristics of the fuel to be considered, which will render it more or less suitable for the use to which it is to be put, and which should not be overlooked in an examination of and in deciding upon its fitness. These are the nature of its ash, the readiness with which it burns, the presence of sulphur, and, when the coal is for naval use, the loss by attrition; and in this paper it will be the aim, after briefly stating the properties and composition of coal, and describing some of the means proposed for estimating its calorific power, to allude to the methods employed in the estimation of these secondary properties.

Since the heat developed by a fuel depends upon the union of the carbon, hydrogen, and other combustible constituents which it contains, with the oxygen of the air, and since also the heat produced by the combustion of measured quantities of each of these substances in oxygen has been determined with great accuracy, it would appear a simple thing to determine the calorific power of a coal by subjecting it to an elementary analysis and calculating from the weights of the elementary substances obtained the heat produced by its combustion; and this method has been followed to a considerable extent in the past, but it has been found in practice to give very erroneous results,—some of the sources of which we will consider.

We have in coal a substance whose composition is very variable and very complex; but, as we have no proximate analysis of coal, it is not possible to make this directly apparent, and therefore we must prove the truth of the statement in another way. The following table gives the results of the ultimate analysis of several varieties of coal, and exhibits the variability in its ultimate composition.

	Lesmahagow Parrot Coal, Miller.	Wigan Cannel, Vane.	Coking Coal, Newcastle, Richardson.	10 Yard, Wolverhampton, Vane.	Newport Steam, Miller.	S. Wales Anthracite, Vane.
Sp. Gr.,	1.251	1.276	1.280	1.278	1.309	1.392
Coke, per cent.,	43.3	60.36		59.21	75.10	92.10
Carbon,	73.44	80.07	86.75	78.57	81.47	90.39
Hydrogen,	7.62	5.52	5.24	5.29	4.97	3.28
Nitrogen,	11.761	2.12	6.61	1.84	1.63	.83
Oxygen,		8.08		12.88	5.23	2.98
Sulphur,	1.145	1.50		.39	1.10	.91
Ash,	6.034	2.70	1.40	1.03	5.51	1.61

An ultimate analysis, however, gives us little real knowledge of the character of a coal, for, as a few experiments will show us, the substances we have determined do not exist wholly in an elementary condition in it. Let us first examine the coal by subjecting a weighed quantity in a confined space to the action of a rarefied atmosphere and heat. We shall find that a considerable amount of gas is evolved from the coal, that this gas is a mixture of compound gases, and that in our ultimate analysis we have estimated their constituents as simple substances. The following table gives the results of some of Mr. Thomas' analyses made in the way described: —

	C. C. of gas from 100 grms., evolved at 100°.	Percentage Composition of Gas.					
		CO_2	CO	CH_4	C_2H^6	O	N
Lignite, Bovey, .	114.3	96.74	2.80	——	——	——	0.46
Cannel, Wigan, .	350.6	9.05	——	77.19	7.80	——	5.96
Jet, Whitby, . .	30.2	10.93	——	C_4H_{10} ?	86.90	——	2.17
Bituminous coal, S. Wales,	55.9	36.42	——	——	——	0.80	62.78
Semi-bituminous, "	73.6	12.34	——	72.51	——	0.64	14.51
Steam coal, "	218.4	5.46	——	84.22	——	0.44	9.88
Anthracite, "	555.5	2.62	——	93.13	——	——	4.25

If, in addition to this, we heat the coal in closed vessels, out of contact with the air, if the coal be other than anthracite we shall find that in addition to the gases evolved, as given above, the coal will yield a large number of substances, solid, liquid, or gaseous, which exist already formed in the coal, or which are produced by the action of heat on substances existing in the coal, and there will be left behind a mass of coke. We may thus prove the complex composition of the coal, but our methods of analysis do not yet admit of our estimating these constituents.

However, our ultimate analyses have shown that carbon is the most important element present, and it is probable that it exists to a large extent in the coal in a free state. Let us consider what would result if we were to estimate the calorific power of the carbon present from a simple determination of the percentage of free carbon. Carbon is one of the elementary substances which exists in several allotropic or unlike states. In all of these its chemical properties are precisely the same, though its physical properties are widely different. These differences are believed to be due to the difference in the arrangement of the atoms in the molecules. Among other differences Favre and Silbermann have found that their heats of combustion differ considerably, increasing inversely as the density, as the following table, embodying their results, shows.

Substance.	Product.	Units of Heat.	Density.
Wood charcoal,	CO_2	8080	1.500
Gas-retort carbon,	"	8047	1.885
Native graphite,	"	7797	2.300
Artificial graphite,	"	7762	——
Diamond,	"	7770	3.530

* "These figures point to the conclusion that the heat of combustion of an elementary substance depends not only on its chemical constitution but also upon its physical state before combustion. It varies not only with the nature of the atoms but also with the manner in which they are grouped together. We cannot deduce the calorific power of graphite from that of charcoal, nor that of the diamond from either. If, then, the mere fact that a substance is composed of pure carbon is not sufficient to determine its heat of combustion, it is not reasonable to suppose that the like information can be acquired in the case of so complex a substance as coal, by a calculation based only on a knowledge of the quantities of carbon, hydrogen and oxygen which it contains." These substances exist in the coal in a state of combination, the compounds of the various elements being mixed together. Hence, when they are burned these compounds must be broken up before they can unite with the oxygen of the air, and, as a general rule, heat is absorbed by the analytical process, and consequently the true heat of the combustion of the coal will be less than the calculated result. Should the compounds, however, be of such a nature that their decomposition is attended with an evolution of heat, the true heat will be greater than the calculated.

Another source of error is due to the fact that the calorific power of hydrogen was determined when that substance was in the gaseous state. Now hydrogen would certainly exist in the coal in a solid or liquid state, and, during the process of combustion, would be converted into a gas. We know that if a solid or liquid is converted into a gas, heat is absorbed. "Therefore, even if the assumption that the 'available' hydrogen is not combined with any of the other elements present in the coal were correct, the calculations themselves would be open to objection, since the hydrogen in its conversion to the gaseous state would absorb heat. Hence, in assuming that the calorific power of solid hydrogen is, like that of gaseous hydrogen, 34,462 units, we commit an error, the existence of which we are certain of, while we are totally ignorant of its magnitude."

Experimental proofs are not wanting to confirm the doubts which theory suggests as to the accuracy of this method of calculation. Two physicists,† Scheurer-Kestner and C. Meunier, have made a long series of experiments on the heat of combustion of coal. They analyzed numerous specimens, calculated their calorific power by the ordinary

* "Coal: Its History and Uses," Prof. Thorpe; page 243.

† Ann. phys. et chim., 4 ser., t. xxi. et. xxvi.

rules, and then made direct experiments to determine their heat of combustion. A comparison of the numbers obtained by calculation and observation proved that they did not agree. Thus in the case of two coals, one from Ronchamp and the other from Creusot, which contained almost precisely the same proportions of carbon, hydrogen, and oxygen, the calorific powers, instead of being identical, were 9,117 and 9,622 respectively. The difference between the real and calculated calorific powers amounted in some instances to as much as fifteen per cent. In the case of two specimens of coal from England, and several from France, the calculated heat of combustion was too small. In that of six kinds of brown coal from France and Germany it was too large, while experiments on several different coals from Russia proved that in these cases the discrepancies between calculation and experiment were comparatively unimportant. It is evident then, that in order to determine the calorific power of a coal with precision we must resort to direct experiments, and that we cannot trust to the calculations based on the elementary composition of the coal. To determine this factor with accuracy we must use the delicate calorimeters employed by the physicist, and at the same time estimate the amount of incombustible matter present. But such precise results are not necessary for the examination of coal for use in the generation of steam; coarser methods will yield results which are sufficiently accurate for this purpose, some of which we will consider.

Thomson has devised a calorimeter which has sometimes been used for determining the calorific power of coal. It consists of a thin, copper cylinder placed inside another, of similar material, which is perforated with holes at the bottom and furnished with a stopcock at the top. The coal to be examined is finely powdered and mixed with ten to twelve times its weight of a mixture of three parts of potassic chlorate and one of potassic nitrate, and this mixture, which will burn out of contact with the air, is then placed in the inner cylinder and the whole submerged under a known weight of water. As the mixture burns, the hot gases bubble up through the holes and warm the waters, until the combustion is completed, when the stopcock is opened and the water flows in to fill the vessel. The heat of combustion is deduced from the elevation of temperature of the vessel and water. The quantities of coal and water employed are so adjusted as to make the calculation extremely simple. It has been shown, however, by Dr. Percy, that there is an error in this method, due to the fact that the bubbles of gas which escape are not completely cooled when passing

through the water, and that the loss of heat on this account is not unimportant. I have not as yet given much thought to this form of calorimeter; but it would seem an easy thing to overcome, by some simple mechanical device, the fault which Dr. Percy has pointed out, and thus secure a useful, though not a precise instrument.

A more practical method among those of a less refined and delicate nature is that of Berthier. This depends upon the fact that carbon, when heated in the presence of litharge, reduces the litharge in accordance with the following reaction,—

$$2\,PbO + C = CO_2 + 2\,Pb$$

and, calculating from the known atomic weights of carbon and lead, we find that for every gram of carbon present, thirty-four and five-tenths (34.5) grams of lead will be obtained. Berthier proposed to perform the experiment by heating the coal, in a finely-divided state, in a crucible, with about forty times its weight of litharge, and continuing the process at a red heat, for some time. The crucible was then allowed to cool; it was then broken, the button of lead extracted, washed, dried, and weighed, and on the above equation the weight of carbon calculated. Suppose we find that a given sample yields 25 grams of lead; then the heating power is $\frac{25}{34.5}$ of that of pure carbon, or assuming that 1 kilogram of carbon raises 7,900 kilograms of water 1° C., 1 kilogram of the sample of coal is capable of raising 5,724 kilograms of water 1° C. To estimate the evaporative power by this method. we have simply to divide the number of units of heat obtained by 537, the units of heat necessary to vaporize 1 kilogram of water at 100° C,

Many objections to this process have been raised, but it seems to me as unobjectionable as any that have been devised. Among other objections it is urged that hydrogen may be present in the coal to a greater extent than the oxygen necessary to combine with it to form water, and that this free hydrogen, if we may so term it, will reduce a part of the lead, and that by assigning the whole to the carbon very serious errors may be introduced. On the other hand, it may be said that according to the reaction,—

$$PbO + 2\,H = H_2O + Pb$$

one part of hydrogen will reduce 103.5 parts of lead, while one part of carbon reduces 34.5 parts of lead, or 3 : 1; but at the same time the units of heat produced by the hydrogen are to those produced by an equal weight of carbon as 4.265 : 1. Now, as the hydrogen is in the solid condition, some heat will be absorbed in converting it into a gaseous form: therefore, in valuing the coal for purchase, when this error exists

it will be in the right direction. In using the method, however, I have found a source of error which has led me to modify the details of it. When a crucible is used it is placed in a furnace where it is difficult to manage, and there is great danger of the reducing gases of the furnace reaching the litharge. Hence, instead of the crucible I employ an iron tube, or gas pipe. Into a piece of gas pipe (ungalvanized) one inch in diameter and one foot long, a plug, tightly fitting, is screwed at one end, and a second piece of pipe, one half inch in diameter and three feet long, is screwed at the other. One gram of the coal to be examined, finely powdered, is now mixed with about forty times its weight of litharge, and poured into the tube and covered with a small quantity of litharge. The tube is then placed in the furnace under a boiler, the open end extending out six inches, and allowed to remain there until upon placing the finger over the open end no pressure is felt. The process does not occupy over ten minutes. The tube is then removed, the closed end rapped sharply on the hearth to cause all the molten lead to descend, and it is then placed in a vise. In the mean time a small box is lined with plaster of Paris for the reception of the lead. This is placed under the tube and the plug is removed and the lead allowed to run into the box. During this operation the tube is rapped with a hammer to facilitate the escape of the molten lead. After the tube is cooled it is frequently found that some of the metallic lead has been caught in the thread, but it is easily got out. Care must, however, be taken not to mistake fused litharge for metallic lead. The lead which is now collected is washed, dried, and weighed, and the calculation made as above. It is found that after a tube has been used two or three times it gives more constant results than at first.

The following determinations, made in this laboratory, prove that this process gives closely agreeing results. One gram of coal was taken for each experiment.

Coal.	Wt. Lead.	Calorific Power.
Lee Wilkesbarre (anthracite)	31.60	7235
"	31.65	7247
"	31.09	7099
"	31.13	7128
Newburgh Orrel (bituminous)	31.61	7238
" "	31.26	7158
Lao-ping (Chinese) "	27.10	6206
" "	27.46	6288
" "	27.47	6290
" "	27.1	6205

Lignite	23.60	5404
"	23.19	5311
"	23.97	5489
"	23.29	5457
"	23.58	5400
"	23.55	5393
Peat	22.75	5209
"	22.63	5182
"	22.42	5135

All but the last four of these analyses were made by Lt. Charles Belknap, U. S. N., Instructor in Physics and Chemistry. The last four were made by Cadet Eng. A. T. Woods, U. S. N.

In order that the process should give reliable results, it is essential that the litharge should be pure. If, as was the case with Johnson's experiments, the litharge contains minium the results will be too low. As some experimenters have found it difficult to obtain constant results with litharge, Mitchell has proposed the use of the ordinary carbonate of lead, but I am disposed to believe that this would be an unwise change, as the composition of the carbonate exhibits greater variations than that of the litharge. It has been said of Berthier's process that in the Admiralty investigation the results exhibit a variation often amounting to a virtual contradiction of the simultaneous results of direct combustion; but Johnson, on the other hand, gives results, to be cited farther on, in which the evaporative power, as determined by experiment, and the results of the litharge test closely agree. It may, however, be urged with some degree of fairness that too small a sample of the coal is taken for examination for us to be able to draw any useful conclusions as to the properties of the mass of the coal from the results; but this argument is equally valid when used against any laboratory process, such as the ultimate analysis, or the determination of the calorific power by a calorimeter; yet if care has been used in selecting lumps of the coal which represent the average character, and then these lumps are finely powdered and intimately mixed, any part of this will fairly represent the average quality of the mass; or we may follow the course prescribed for the assay of an iron ore. Break up in an iron mortar forty or fifty pounds of the coal into pieces that will pass through a sieve with one-half inch meshes. Thoroughly mix the fine and the coarse. Now break up about ten pounds of this mixture so that it will pass through a sieve with one-fourth inch meshes. Mix well: take one pound of this and pulverize

until it will pass through a sieve of sixty meshes to the linear inch. Mix well: take out fifty grams, pulverized in agate mortar and pass through muslin bolting cloth. Of course in the analyses given the whole of this course of procedure was not followed, as we sought only to test the accuracy of the method by concurring results and not to analyze the coal.

L. Gruner* has also arrived at the conclusion that the calorific power of a coal cannot be accurately determined by its elementary analysis. He holds that a more correct estimate of the heating power of a coal is obtained by determining the average amount of coke which it yields. The higher the yield of coke the greater is the heating power, but this heating power does not diminish in the same ratio as the yield of coke; thus for a decrease in the yield of coke from 80.4 to 59 per cent., the heating power diminishes only from 9622 to 8215. In using the percentage of coke as an estimate of the value of the coal Gruner conflicts with other investigators who hold that it is an uncertain guide, since wide differences have been found in the evaporative power of different coals which possessed an equal average amount of fixed carbon. From the consideration of the amount of coke it will be seen that he is led to a system of classifying coals which is almost identical with Johnson's published in 1844.

He groups the different kinds of coal arbitrarily in five classes, as follows, though there is no distinctly marked division between any two.

Distinguishing Property	Elementary Composition: C	H	O†	Relation of $\frac{O}{H}$	Residue of Coke on Distillation.	Appearance of Coke.
Dry coal, burning with a long flame.	75 to 80	5.5 to 4.5	19.5 to 15	4:3	0.50–0.60	Powdery, or slightly caked.
Bituminous coal with long flame, or gas coal.	80 to 85	5.8 to 5	14.2 to 10	3:2	0.60–0.68	Fused, but deeply seamed.
True bituminous coal, or smithy coal.	84 to 89	5 to 5.5	11 to 5.5	2:1	0.60–0.74	Fused, and tolerably compact.
Bituminous coal with short flame, or coke coal.	88 to 91	5.5 to 4.5	6.5 to 5.5	1	0.74–0.82	Fused; compact; very slightly seamed.
Anthracite coal.	90 to 93	4.5 to 4	5.5 to 3	1	0.82–0.90	Powdery.

* Ann. Min. 1873, IV, 169.

† The O includes N, but the latter rarely exceeds 1 per cent. of the combustible matter.

The length of the flame depends on the amount of volatile matter; the combustibility of the coal on the nature of the ash. If the ash contains iron and lime, a slag forms; if it contains alumina and silica, it remains in a powdery form, which is more favorable to the combustion of the coal. The first class, *dry coal with long flame*, is used for making coke. The Sp. Gr. is about 1.25. The color is usually brownish. A proximate analysis gives—

Coke.	Ammoniacal liquor.	Tar.	Gas.	Volatile matter.
50–60	12–5	18–15	20–30 per cent.	50–40 per cent.

Calorific power, 8200–8300. As soon as the carbon exceeds 80 per cent. and the oxygen is under 15 per cent., this class of coals begins to coke on heating.

(2) *Bituminous coal with long flame* (gas coal).—The coke obtained from this coal is always caked together. The coal itself is hard, the fracture laminated. The Sp. Gr. is 1.28–1.30. Color, pure black, with strong luster. Proximate composition—

Coke.	Ammoniacal liquor.	Tar.	Gas.
60–68	5–3	15–12	20–17 per cent.

Volatile matter, 40–32 per cent.; Calorific power, 8500–8800.

(3) *True Bituminous, or "Smithy Coal."*—Color, pure black, with high luster; brittle, with laminated fracture. Fuses when burning, leaving the coke in a compact cake. Sp. Gr. 1.3. Proximate analysis—

Coke.	Ammoniacal liquor.	Tar.	Gas.
68–74	3–1	13–10	16–15 per cent.

Volatile matter, 32–26 per cent.; Calorific power, 8800–9300.

(4) *Bituminous coal with short flame, or "Caking coal."*—This class exhibits the same properties as the previous one; its luster, however, is not so great. It is very brittle, and although it is termed *dure* in France, this means that it does not burn away quickly. It does not contain much volatile matter, and is consequently difficult to kindle. Sp. Gr. 1.30–1.35. Proximate composition—

Coke.	Ammoniacal liquor.	Tar.	Gas.
74–82	1–1	10–5	5–12 per cent.

Volatile matter, 26–18 per cent.; Calorific power, 9300–9600. One kilogram of this coal evaporates 9.75 kilograms of water.

(5) *Anthracite Coal.*—This coal forms the link to pure anthracite. It is black, and shows dull streaks. Its cohesion is slight, but increases the nearer it approaches the character of pure anthracite. Sp. Gr. 1.35–1.40. Proximate composition—

Coke.	Ammoniacal liquor.	Tar.	Gas.
82–90	1–0	5–2	12–8 per cent.

Volatile matter, 18–10 per cent.; Calorific power, 9200–9500. One kilogram, calculated without ash, evaporates 9.15 kilos of water; but as it usually contains 10–11 per cent of ash, its real evaporative power is 8.12 kilos.

C. Hilt* likewise regards the yield of coke, together with the amount of ash, as of especial importance in the valuation of coal. He gives a classification of coals according to the ratio between the quantities of bitumen and coke which they yield when ignited in a covered crucible.

	Bitumen : Coke.		Bitumen : Coke.
1.—Anthracite, . . .	1 : 2	to	1 : 9
2.—Flint coal (old), yielding but little gas,	1 : 9	to	1 : 5.5
3.—Coking coal, ...	1 : 5.5	to	1 : 2
4.—Coking gas coal, . . .	1 : 2	to	1 : 1.5
5.—Flint coal (young), yielding much gas,	1 : 1.5	to	1 : 1.25
6.—Gas coal, ...	1 : 1.25	to	1 : 1.1

If the bitumen or volatile matter be expressed in terms of ash free coke we have—

Bitumen.		Bitumen.
No. 1 contains 5 to 10 pr. ct.	No. 4 contains 33.3 to 40 pr. ct.	
No. 2 contains 10 to 15.5 pr. ct.	No. 5 contains 40 to 44.4 pr. ct.	
No. 3 contains 15.5 to 33.3 pr. ct.	No. 6 contains 44.4 to 48 pr. ct.	

About the year 1842 Prof. W. R. Johnson began, under the auspices of the Navy Department, a series of experiments to determine which, among our many varieties of coal, was best adapted to and most economical for the purposes of the navy. Similar investigations were also subsequently undertaken by Dr. Lyon Playfair and Sir Henry de la Bêche with the British coals. In both these researches the following principles were stated as governing the end sought.

1st. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words it should be able to produce a quick action.

2nd. It should possess high evaporating power—that is, be capable of converting much water into steam with a small consumption of coal.

3d. It should not be bituminous, lest so much smoke be generated as to betray the position of vessels of war when it is desirable that they should be concealed.

4th. It should possess considerable cohesion of its particles so that

* Ding. Pol. Jour., CCVIII. 424.

it may not be broken into small fragments, by the constant attrition which it may experience in the ship.

5th. It should combine a considerable density with such mechanical structure that it may be easily stowed away into small space—a condition which in coals of equal evaporative values often involves a difference of more than twenty per cent.

6th. It should be free from any considerable quantity of sulphur, and it should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

Great importance was attached to the determination of the evaporative power which was accomplished by burning weighed quantities of coal under a boiler of known dimensions and measuring the quantity of water evaporated. Of course, at the same time the area of the grate surface, of the combustion chamber, of the heat absorbing surface and the length and area of the flues were also known. The conditions under which the experiments were conducted were apparently like those which exist in practice, and promised to lead to positive results, yet the results given in Johnson's Report in 1844, and the British series of reports, concluded in 1851, after showing that no fixed relation exists between the calorific power as calculated from the results of analysis and the evaporative power of the coal, also "prove, by the very differences which they exhibit, that the only trustworthy method of determining the value of a fuel for steam purposes is that of practical experiment under the boiler in which it is to be used, and where several tons and not pounds are consumed." The results of such experiments cannot, however, be considered as applying to furnaces and boilers dissimilar to those actually used. The conditions attending the advantageous combustion of coal resemble those which obtain for the combustion of coal gas for illuminating purposes. To obtain the highest photometric power for a given gas, a certain form of burner, number of apertures, rate of flow, and length of chimney are found essential, and these are determined by experiment. To get the maximum effect with a gas from another source, some or all of these conditions must be varied. For this reason, and others which might be given, notwithstanding the conclusions of the Admiralty's Board, the results of laboratory experiments which are conducted under similar conditions for different coals cannot but be of value in deciding the fitness of a fuel for the purpose to which it is to be applied.

In the English experiments, besides the determination of the evaporative power, Berthier's litharge test was applied, and the loss by attrition

was also estimated. "This factor, which is of extreme importance in steam navigation, becomes reduced the more the cleavage of the coal or the shape of the fuel approaches the form of a cube. In order to attain at least a relative idea of the waste occasioned by transport, i.e., of the attrition of the individual pieces of coal against each other, and the conversion of unbroken coal into dust, unfit for use, which is occasioned by the motion of the vessel, the various specimens were rotated in a drum for the same length of time, and the dust thus produced separated and weighed." The subjoined table shows some of the results of the British investigation. 1. No. pounds of water at 100° C. converted into steam by one pound of fuel. 2. Ditto after deducting portions of coke contained in ash. 3. Theoretical evaporative power in pounds of water at 100°, as calculated from litharge test. 4. Weight of coal per cubic foot of stowage in pounds. 5. Ditto per solid cubic foot deduced from specific gravity. 6. Percentage loss by equal amount of attrition.

Kind of Fuel.	1	2	3	4	5	6
Welsh—						
Jones & Co. Anthracite,	9.46	9.70	13.84	58.25	85.79	68.5
Ward's Fiery Vein,	9.40	10.60	16.40	57.43	83.85	46.5
Graigola,	9.35	9.66	16.72	60.17	81.11	49.3
Duffryn,	10.14	11.80	15.64	53.22	82.72	56.2
Pouty Pool,	7.47	8.04	14.31	55.70	82.35	57.5
Ebbro Vale,	10.21	10.64	16.68	53.30	78.81	45.0
Bedwas,	9.79	9.99	14.70	50.50	82.60	54.0
Scotch—						
Dalkeith Jewel,	7.08	7.10	13.77	49.80	79.67	85.7
Wallsend Elgin,	8.46	8.67	15.15	54.60	78.61	64.0
Fardel Splint,	7.56	7.69	15.12	55.00	78.61	63.0
Grangemouth,	7.40	7.91	14.85	54.25	80.48	69.7
English—						
Broomhill,	7.30	7.66	13.20	52.50	77.99	65.7
Park End, Sydney,	8.52	8.98		54.44	80.05	55.0
Irish—						
Slievenagh,	9.85	10.49	16.21	62.80	99.57	74.0
Mean of three patent fuels,	9.27	9.66	15.44	66.48	70.66	

From the examination of this table and a comparison of columns 2 and 3 it will be seen that the litharge test occasionally gives results at variance with those obtained by the evaporative test, but as a rule they are concurrent. When the results disagree it would be interesting to know what results are actually obtained in practice.

The results obtained by Johnson are more concurrent, and are

exhibited in the following table, together with the results of M. Baudin by the litharge method:

No. of specimens assayed.	Nature of coals.	Evaporative power, by experiment.	Lead reduced by 1 of combustible.
8	7 Penn. anthracite, 1 natural coke of Va.,	10.537	32.157
11	Md. and Penn. free-burning coals,	10.877	31.736
10	Va. bituminous,	9.523	28.194
8	Foreign and western highly bituminous,	8.710	27.740
3	French anthracites,		33.520
3	Free-burning coals,		32.040
3	Bituminous coal,		29.830
3	Highly bituminous,		27.586

Prof. Johnson believed the lead-reducing power of the coal to depend on the carbon constituent, and cites the following instances in support of this view: The ultimate analysis of Cambria county, Penn., coal gave 91.955 per cent. of carbon, and experiment showed its lead-reducing power to be 31.464. Again, ultimate analysis showed Clover Hill, Va., coal to contain 83.393 per cent. of carbon, and this on experiment yielded 28.527 parts of lead. Now the ratio of the percentages of carbon is to that of the lead produced as follows: $\frac{91.955}{83.393}=\frac{31.464}{x}$, where $x=28.534$, which may be considered as identical with that obtained by experiment.

Important experiments upon the evaporative power of American coals and of the evaporative efficiency of different boilers and furnaces have been carried on for some years and are still being pursued by a board of Engineers of the Navy, under the direction of Chief Engineer B. F. Isherwood, and it is probable that, as our data accumulate, we may be able to discover some closer relation between the results of experiment and those of use; but the value of these results would be greatly enhanced if the fuels employed were also subjected to analysis, and their calorific powers determined by the various methods suggested, for we might, from the data thus collected, be able to effect the complete solution of the problem stated at the opening of this paper.

The presence of sulphur in coal may sometimes be detected by simple inspection; for as it frequently exists in the form of iron pyrites, these, or the rust produced by the weathering of the crystals, may generally be readily observed. Sometimes these crystals may be so

finely disseminated through the mass that they cannot be seen, or the sulphur may be present in another form. A rough way for detecting the sulphur may then be used, which is as follows: The powdered coal is fused in an iron vessel with twice its volume of carbonate of soda. The fused mass, when cold, is then placed on a bright silver or copper surface, and moistened with water. If sulphur is present the metallic surface will be blackened by the formation of a film of sulphide. To make sure that the carbonate contains no sulphur it must first be fused and tested in the same way. I have now in hand some experiments by which I hope to test for sulphur at the same time that I am making the lead test, the results of which will be given later.

The nature of the ash, the readiness with which the coal burns, and the determination of the amount of ash, are factors which are only to be obtained by the combustion of the coal. The process usually followed, of burning the weighed coal in a weighed iron vessel, is correct in principle, but of course as conducted in the laboratory the errors incident to the corrosion of the iron when heated are avoided by the use of non-corrosive material. In every way, too, the process used there is more delicate: yet the process used in the engine-room gives fair results.

NOTE—The calorific power given by Scheurer, Kestner and Meunier were determined by experiment with Favre & Silbermanns calorimeter. The data given by Gruner are also the results of experiments.

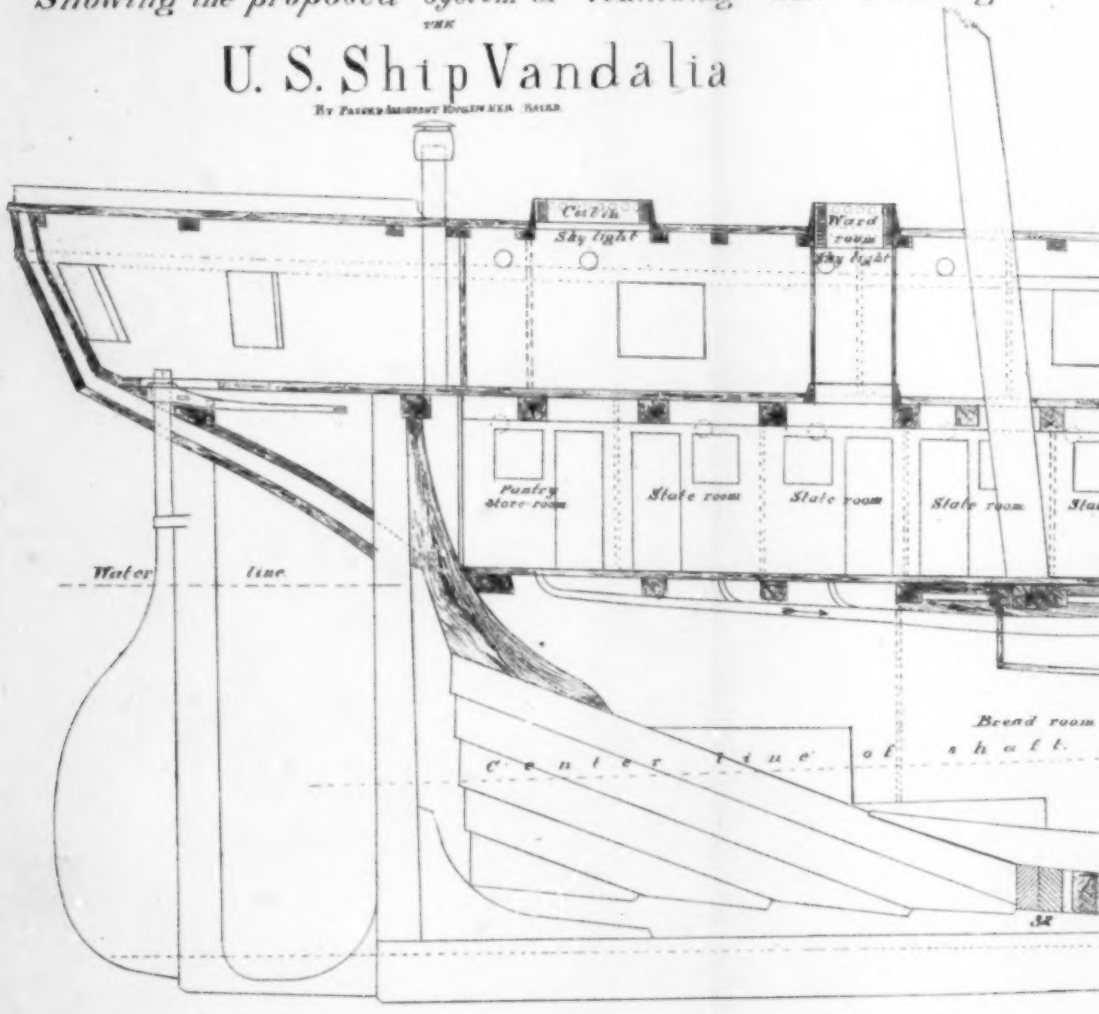
PLATE I

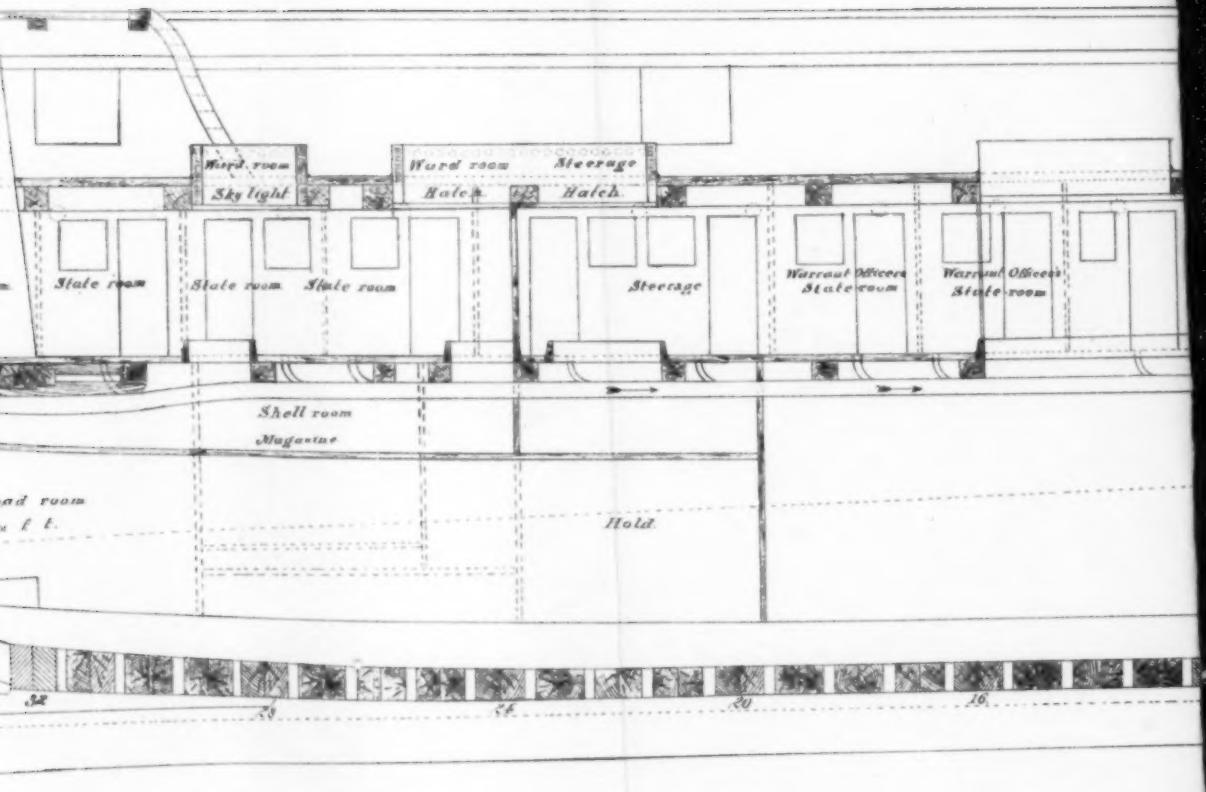
Showing the proposed system of ventilating and warming

THE

U. S. Ship Vandalia

By Passed Assistant Engineer Baird.




Ward room
Sky light
Ward room
Steerage
Hatch
Hatch
State room
State room
State room
Steerage
Warrant Officers
State room
Warrant Officers
State room
Shell room
Magazine
Hold
32
28
24
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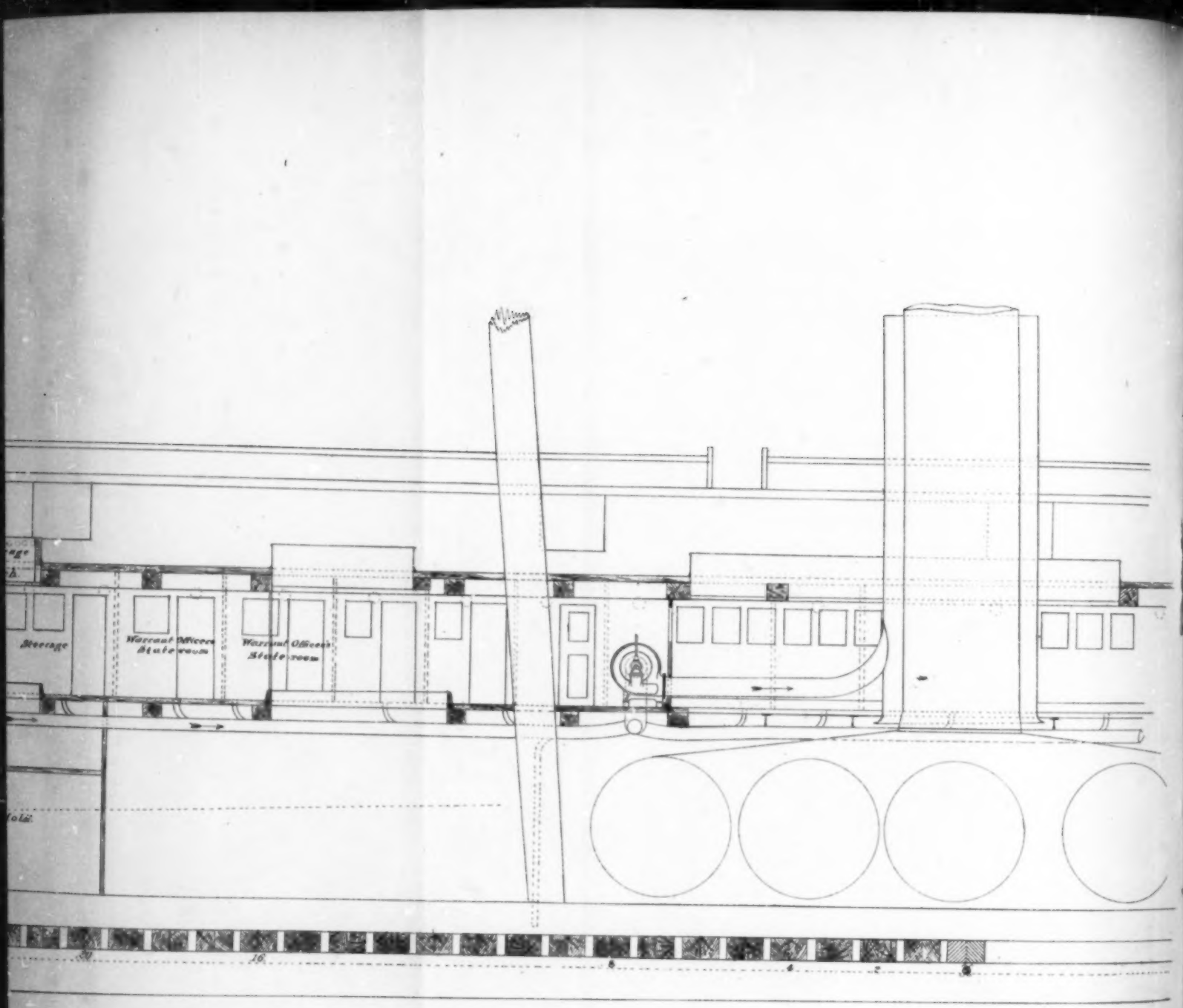
16


Steerage
Warrant Officers Staterooms
Warrant Officers Staterooms

WASHINGTON BRANCH,

APRIL 13, 1880.

MEDICAL DIRECTOR T. J. TURNER, U. S. N., in the chair.

THE VENTILATION OF SHIPS.

BY PASSED ASSISTANT ENGINEER G. W. BAIRD, U. S. N.

MR. CHAIRMAN AND GENTLEMEN:—

I think that the carbonic acid exhaled from our lungs or produced by combustion on board ship is not nearly so injurious to health or comfort as the foul gases of the bilge or the organic matter from our exhalations. While serving on board the Pensacola—a vessel not overcrowded—we found the organic matter, deposited upon the knees, beams and ceiling of the vessel, on the berth deck, sufficiently thick to be wiped off by a pocket handkerchief, and clearly distinguished upon its surface.

In 1854 Dr. Thompson found that "the air of London when passed through oil of vitriol communicated a dark tinge to it, and if large quantities of air were passed through distilled water, the inevitable result was the formation of fungi." And Dr. R. Angus Smith, (Op. Cit. p. 217,) tested the air for organic matter and found the proportion in the air. This table, published in the *Chemical Gazette* of 1859, is as follows:—

LOCALITIES.	Number of grains of organic matter in 100 cubic inches of air.
Manchester, England,	52.9
In a pig-sty,	109.7
Thames, in warm weather,	58.4
Thames, Lambeth,	43.2
Thames, Waterloo bridge,	43.2
London, in warm weather,	29.2
London, after a thunder storm,	12.3
Northern Italy,	6.6
German Ocean,	3.3
Lake Lucerne,	1.4

It will be seen that the amount of organic matter varies considerably in different localities and under different circumstances, and I regret that I am unable to give the proportion of this poison found on board our ships. It is a subject now under investigation by the surgeons of the Navy, and, though the tests for it are complicated, I hope at no distant day to see a full analysis, as found on board all classes of our vessels, published by the Medical Bureau.

Pasteur supposed "that germs of infusoria were present in all air, and the cause of fermentation and putrefaction," and Van der Broeck, Shroeder and Deuch have confirmed his views. They found that almost all organic substances, even those of ready putrefaction, such as blood, fibrine, albumen, sugar, etc., were preserved unaltered when heated to the boiling point in a bottle, stopped by a loose plug of raw cotton, so that in cooling the entering air would be filtered and deprived of floating solid substances.

The amount of carbonic acid in the air seems to be as inconstant as that of organic matter. In the densely populated parts of Europe we find a much greater quantity than in any parts of America, excepting in the volcanic regions of South America. Dr. Wetherell estimates the mean amount of carbonic acid in the air, for all parts of the world, to be four parts in ten thousand, so that in estimating the amount of air necessary for the dilution of this gas to its normal, we will base our calculations on this fraction.

The quality of this gas appears to be more deadly than its quantity, for I have read that La Blanc found that "a bird died in a room containing less carbonic acid than existed in the air of many apartments he had examined; and a dog survived longer in air containing the enormous amount of nineteen hundred and ninety-one volumes per ten thousand of carbonic acid than in an atmosphere from burning charcoal in which three hundred and one volumes of this gas were present." The cause of the latter superior deadly effect was attributed, by competent authority, to the presence of the poisonous carbonic oxide, emitted by imperfect combustion.

The presence of carbonic acid on board ship, when produced by exhalation, is an indication of the presence of organic matter, and they bear, in that case, nearly a constant relative proportion to each other, so that the tests now being made on board our ships for carbonic acid may be relied upon as an index for organic matter as well. What this ratio is I am unable at present to say, but I hope soon to see published the work our surgeons are now doing on this subject.

Pettenkoffer, La Blanc, Roscoe and others have made some very interesting experiments on the escape of carbonic acid through the crevices of rooms, condensation upon the surfaces of, and diffusion through the walls of apartments, but I have not been able to find any similar tests for organic matter. Dr. Wetherell, in his celebrated experiments found the carbonic acid in the public schools of Washington ranged from 9.342 parts in ten thousand, to 17.184 in ten thousand, and during the same month he found only from 4.275 to 7.355 parts in the United States Senate Chamber, and while there were no complaints from the schools of ill ventilation, we have heard many from the Capitol extension. There must have been some other offensive matter than the carbonic acid in the Senate and House of Representatives, and it may have been organic matter, for we are informed that Professor Leeds found decaying animal and vegetable matter in the very conduits which bring the air from the fans to the Senate Chamber and the House of Representatives.

On board ship we have more than this to contend with. On board all new ships, and also those which have been lately repaired, we find the bilge pumps frequently choked up by chips and shavings. As the bilges are cleaned and inspected before a vessel leaves the navy yard to commence a cruise, we naturally ask where these shavings come from? We observe they appear most abundant when the ship has considerable motion, and infer that they must have worked or fallen down from between the timbers where the ship is ceiled in. As this stuff decays it evolves gas abundantly. Letting water into the bilge and pumping it out daily will remove the bad odors, but if the watering be neglected for a single day the stench is worse than usual. In order to prevent the evolution of gases by the bilge we must keep it dry. The large amount of air received into a ship through the wind sails alone is more than enough to purify the air so that no trace of odor could be detected, were the air properly distributed; but this blast takes the most direct course to the nearest outlet and escapes, causing, in its passage, but feeble eddies in the other parts of the vessel. It is evident that we must *remove* these foul and poisonous gases first, and afterwards direct our attention to the supply of fresh air.

Direction of the Products of Respiration.—The question which now presents itself is whether it is better to remove foul gases through openings near the floor or near the ceiling.

Mr. Goldsworthy Gurney, who ventilated the House of Commons, informs us that the breath is forced downwards to the ground from the

nostrils, and I believe he went so far as to declare that it took the direction of a definite mathematical curve. From the experiments of Roscoe, Dr. Wetherell, and others, we learn that the atmosphere, in large rooms occupied by man, is as rich in carbonic acid near the ceiling as at the floor. Those who advocate the system of ventilation by aspiration (or exhausting the foul air) have not always stated this fairly, having cited isolated cases of analyses instead of taking the mean of a great many observations. The first one who attacked this problem fairly was Dr. Wetherell himself, and I cannot do better than to quote him *verbatim*. "On March 27, 1865, at 1½ P. M., in the laboratory of the Smithsonian Institution, the temperature of which was 69.26° Fahr., a delicate thermometer, held in the hand for several minutes, indicated 95.36° Fahr. Held in the mouth, and observing the degree by the aid of a mirror, it indicated the same temperature. Upon smoking a pipe with a stem of wood six inches long, slowly, with the thermometer also in the mouth, the temperature did not sensibly rise. Having thus obviated a source of error from any supposed heat in the tobacco smoke, I experimented upon the air currents of the breath, both while sitting and standing, following them readily by the aid of the smoke. Before expulsion the smoke was held in the mouth for a short time to insure its temperature to be the same as that of the breath, and the hot pipe was held or placed aside. When the smoke is expelled gently from the nostrils, as in the act of breathing, it proceeds downward a foot or less, and then rises rapidly."

I think this experiment, which any one may easily repeat, should set aside the vicious theory that the heavy carbonic acid in the breath we exhale carries it rapidly and certainly to the floor. The many analyses of air taken from different parts of a large room do not show that its superior specific gravity carries it certainly downward. The carbonic acid probably diffuses itself rapidly with the pure air present, and its direction is affected very much more by natural air currents than by its superior weight. In his experiment the Doctor neglected to note whether or not the windows were open, or whether any currents were induced by the fire, which at that season was burning; and though he demonstrated fairly that the exhalations do not essentially flow downward, I think he has not proved the opposite.

Fig. 1 is a transverse section of the fifth state room on the port side of the Vandalia's ward room, which is opposite a hatch and is near a wind sail. By means of a delicate Casella anemometer I have been enabled to ascertain the direction of the air from the wind sail, and

Fig. 1.

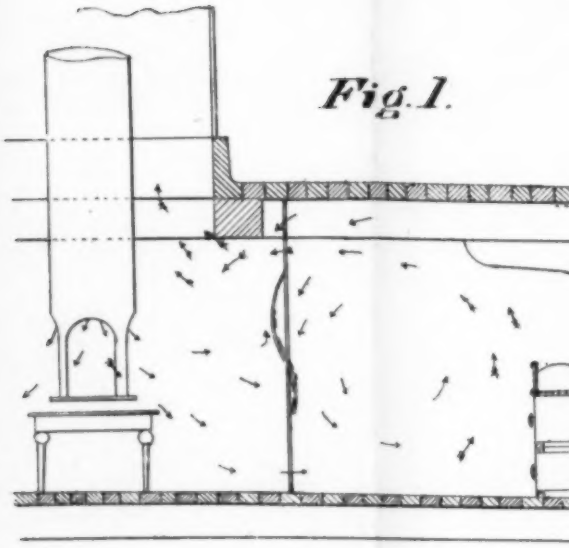
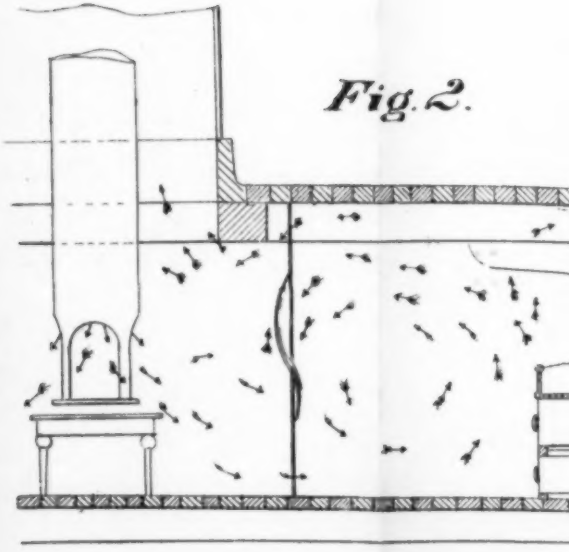
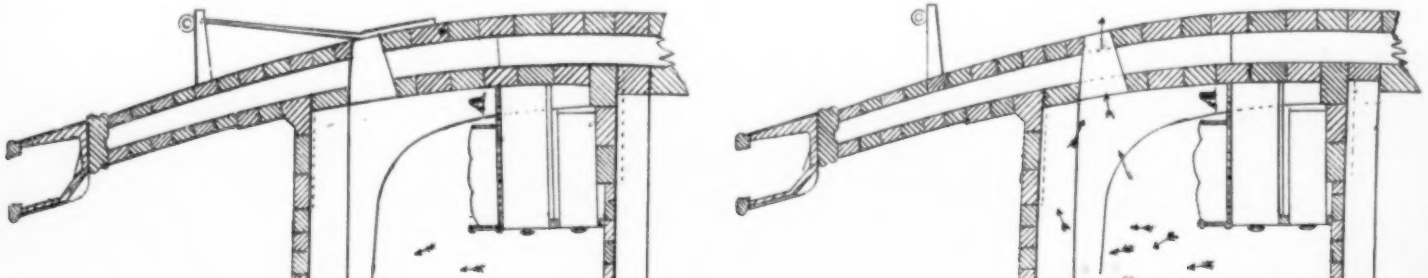


Fig. 2.





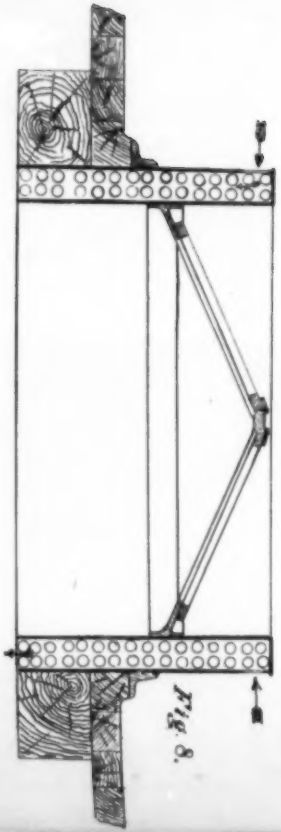


Fig. 4.

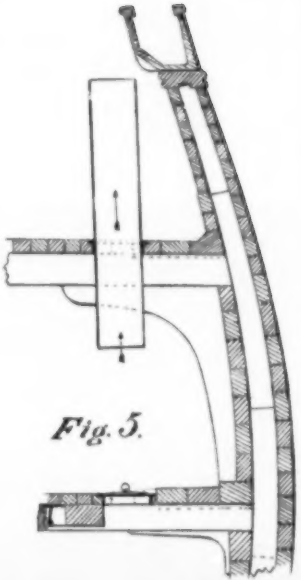


Fig. 5.

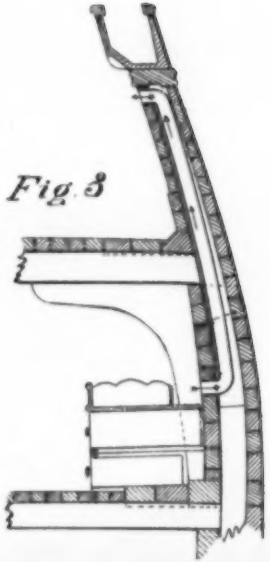


Fig. 3

have indicated it in fig. 1 by arrows. The anemometer used is so sensitive that its vane moves freely in a current of air that will not perceptibly deflect the flame of a candle. The curtain was kept open both at the top and bottom, in order to permit a free circulation of the air, and when the air port was closed there could not be found the slightest current above the berth. On one occasion, when the air port was closed, the observations, which were taken immediately on rising, showed 19.036 parts of carbonic acid in a specimen of air taken from behind the berth, (at A, fig. 1,) while a volume of air from the wind sails of 11,016 cubic feet per hour was flowing through the room, in the path indicated by the arrows. On another occasion, with the air port open, similar observations showed 6.662 parts of carbonic acid while 21,600 cubic feet of air per hour flowed through the room, in the paths indicated by the arrows in fig 2. The analyses for carbonic acid were made by Assistant Surgeon George Arthur, who employed Park's method, while the air currents were measured by the writer.

It is evident from the above experiments that the exhalations should be breathed into the air current, or that we must sleep in a draught if we would breathe pure air. In order to supply an outlet for the vitiated air which accumulates behind the berths, Dr. Arthur proposes an exhaust tube, as shown in fig. 3. With natural ventilation or with a forced blast there can be no doubt that Dr. Arthur's tube would be of great value in exhausting the impure air, and with ventilation by mechanical aspiration this tube would reverse its action and supply the fresh air. From the direction taken by the currents, as delineated in fig. 1, it would appear that Arthur's tube is well located, and also that the exhaust tubes on board the Richmond, which are above and back of the berths, are properly placed, but I think we should not lose sight of the necessity of quickly drying the decks, and I would, therefore, recommend placing the exhaust openings in the floor, and depend on Arthur's tubes as inlets. From the experiments referred to above, made with the air port closed, and again with it open, we have another evidence that the air currents take the direction of least resistance; and in order to uniformly disseminate the pure air, and to insure its reaching every part of the ship, we must remove the impure gases from the points where they are generated, and it is obvious that we must employ some system of aspiration, either natural or artificial.

QUANTITY OF AIR.—Not many years ago it was believed that the quantity of air needed to keep an apartment wholesome was merely equal to the amount exhaled, which is about 12 cubic feet per hour;

but a set of experiments to determine the quantity necessary to dilute the carbonic acid exhaled by the lungs to something near the normal quantity, indicated that 3 cubic feet per minute, or 180 per hour, would be sufficient. Later observers concluded that the necessary amount would be that which would dissolve the aqueous vapor expelled by the lungs and skin, thus preventing the hygrometric condition of the air from rising too far above that of the surrounding atmosphere, and that 5 cubic feet per minute, or 300 per hour, would be sufficient.

Assuming that the air admitted upon the berth deck of a ship be mixed by at once diluting the carbonic acid present, we will find it an easy matter to calculate what the volume of that air shall be. Let us take an example from the steam sloop Vandalia, one of our latest ships, and one that is considered to have relatively good ventilation. On the 12th of August, 1879, Assistant Surgeon Geo. Arthur collected a jar of air from the middle of the ward room, and by subsequent analysis (by Park's method,) found it to contain 6.983 parts of carbonic acid in 10,000 parts. At the same date and hour, the writer found the quantity of air (as measured by a Casella anemometer,) admitted into the ward room to be 96,780 cubic feet per hour or 9,678 cubic feet for each of the ten occupants, which is vastly more than is necessary to keep the air at the purity found by Dr. Arthur. Assuming the air supplied by the wind sails to contain 4 parts of CO_2 per 10,000, which is the normal, we have all the data necessary to ascertain the volume of air essential to keep the air at the above mentioned purity.

Let Q = the quantity of air, in cubic feet, to be supplied.

n = the number of men, - - - - - 10

a = the number of cubic feet of carbonic acid exhaled per hour per man, - - - - - 0.686

b = the fraction of carbonic acid normal to the atmosphere, - - - - - - 0.0004

c = the fraction of carbonic acid found in the air of the apartment, - - - - 0.0006983

Then

$$na+Qb=(Q+na)\,c$$

$$na+Qb=Qc+nac$$

$$na-nac=Q\,(c-b)$$

$$Q=\frac{na-nac}{c-b} \quad - \quad - \quad - \quad (1)$$

And, substituting the numerical value for the letters in the formula, we have

$$\frac{(10\times 0.686)-(10\times 0.686\times 0.0006983)}{0.0006983-0.0004} = 22{,}981,$$

or $\frac{22{,}981}{10} = 2{,}298$ cubic feet of air per hour per man. Roscoe made this calculation by a different method, and, as it has been adopted by Dr. Wetherell and others, it will not be out of place to verify the above results by comparison with Roscoe's method.

Let V represent the volume of air free from carbonic acid that would be required, and a = the fraction which the impurity of the air (0.04 per cent.) is of the limit of the impurity in the mixture (0.06983 per cent.), and let Q = the volume of normal air required.

Then $Q = V+Va+Va^2+Va^3\times Va^4+ \quad . \quad Va^n \quad . \qquad (2)$

It will be sufficient to calculate the first five terms only of this expression:

$$0.06983 : 99.93017 :: 6.86 : V = 9{,}817$$

$$a = \frac{0.04}{0.06983} = 0.5728$$

$$a^2 = 0.328$$
$$a^3 = 0.188$$
$$a^4 = 0.107$$

$$V = 9817$$
$$Va = 5623$$
$$Va^2 = 3219$$
$$Va^3 = 1845$$
$$Va^4 = 1050$$
$$Q = 21554$$

or 2,155.4 cubic feet per hour per man, instead of 2,298 as found by formula (1), though it will agree nearer and nearer the farther it is followed.

But let us compare the volume of air actually admitted with the quantity essential to preserve the purity mentioned. We find that a Casella anemometer, purchased from respectable dealers in Philadelphia, (Queen & Co.), verified by the U. S. Signal Office in Washington, indicated the enormous quantity of 96,780 cubic feet per hour, or $\left(\frac{96{,}780}{22{,}981} =\right)$ 4.2 times the necessary amount. Had this 96,780 cubic feet of air per hour mingled with and diluted the carbonic acid in its passage through the ward room, Dr. Arthur would have found very much less of that poisonous gas in his analyses. By transposing from formula (1) we can calculate the number of parts of CO_2 he would have found, viz.

$$c = \frac{na + bQ}{Q + na} \quad . \quad . \quad . \quad (3)$$

and by substituting the numerical values we will have

$$\left(\frac{10 \times 0.686 + 96780 \times 0.0004}{96780 + 10.686} = \right) 4.71$$

parts in 10,000, or an atmosphere almost as pure as that outside the ship.

It may be now asked, why does not this great quantity of air whirled into the ship through the wind sails accomplish its object? The question has been answered many times. The air, after leaving the wind sails, takes the shortest and most direct route to the nearest outlet and escapes, and all the benefit we derive from it is by the eddies it creates; and the only way to utilize it is by causing it either to enter in a larger number of smaller jets or, what is equivalent, cause it to escape through a large number of separate openings.

Now let us take an example from the berth deck of the Vandalia, the place where the sailors are berthed. Their hammocks are swung side by side, from the beams over head, leaving an unobstructed passage for the air underneath, and there are no such bulk heads between them as between the officers' berths. An observation was taken at 5.30 A. M. Sept. 22, 1879, a few minutes after the men left their hammocks. The wind was on the port bow, and was blowing at the rate of 600 feet per minute. There were 5 air ports open on the weather side, through which the mean velocity of the air entering was 125 feet per minute, and, as each air port presented an area of 0.306 square feet, the aggregate volume of air entering through them was, in cubic feet per hour, 11,475. There were two wind sails in use at this part of the deck, each presenting an area of 2.75 square feet through which the mean velocity of the wind was 287.5 feet per minute, making, in cubic feet per hour, 94,875, or a total of (11,475+94,875 =) 106,350.

There had been berthed there that night 130 men, so that the air per man was $\left(\frac{106,350}{130} = \right) 818$ cubic feet per hour. The carbonic acid found on this occasion by Dr. Arthur was 13.18 parts in 10,000, whereas, had the fresh air been thoroughly mixed with the air on the deck, it would have been (from formula 3)

$$\left(\frac{na + Qb}{Q + na} = \frac{130 \times 0.686 + 106,350 \times 0.0004}{130 \times 0.068 + 106,350} = \right) 12$$

parts in 10,000, or a quantity very much nearer the theoretical than that found in the ward room.

In order to ventilate the berth deck of this fine sloop by means of

an exhaust fan, we have first to determine the size of the fan, conduits and registers. There are 120 established billets on the berth deck for hammocks, besides rooms for four warrant officers, steerage capacity for twelve officers, and ward room quarters for twelve more, making a total of 148 persons. Allowing each one 2,298 feet of air per hour, we will require ($2298 \times 148 =$) 340,104 cubic feet.

We find exhaust fans advertised by the Boston Blower Co., (fig. 4,) capable of producing a velocity of 75 feet per second,* which is 270,000 feet per hour.

The area of a conduit or of the exhaust fan opening to pass 340,104 cubic feet per hour at 270,000 linear feet per hour is $\left(\frac{340,104}{270,000} = \right) 1.26$ square feet, or ($1.26 \times 144 =$) 181.44 square inches, or a tube having a diameter of 15½ inches, nearly. The nearest regular merchantable size to this would be the 45-inch exhaust fan, the opening of which is 15½ inches diameter. It would be advisable to place the fan as near the deck as practicable, having four branch pipes, one running forward on each side of the deck, and one running aft on each side.

The diameter of the main conduit, if of circular section, would be equal to the induction opening of the fan, i. e. 15½ inches, (and if of square section it would be 13½ inches,) while the four branch openings would be 6¾ inches each. In practice it would be necessary to increase the four branch pipes to 8½-in. diameter, to prevent the resistance of surface friction and *contracted vein* from becoming greater than in the main pipe.

In order to discharge the same quantity of air from each state room, the registers, or openings, into the main conduit from these rooms would necessarily increase in size the farther they were placed from the fan. The size of openings cannot be calculated without experimental data, and I can find no record of any experiment on similar tubes with a number of openings. There would, however, be no mechanical difficulty involved in this, for registers or inlet valves would necessarily be placed at each opening, and after the fan had been put in use the valves could be graduated and stops put at the limit.

Now let us consider the value of the air shafts with which our vessels are sometimes provided, and also the air jacket that surrounds the smoke pipes of all our steamers.

In July, 1879, the Vandalia towed a section of dry dock from Chester, Pa., to Pensacola, Fla., which so retarded the vessel's speed that

* At 1,400 revolutions per minute.

no draught was perceptible in the wind sails, and the temperature on the berth deck rose to an uncomfortable height; the surgeon's test for carbonic acid indicated a larger amount of that gas than usual. The men could not sleep well in their hammocks, and many of them were permitted to sleep on the spar deck under the cover of the awnings; the firemen and coal heavers were becoming enervated, and two of them fainted at their work, from exhaustion. We then improvised a chimney on each side of the deck, by removing a deck plate and placing over the hole one of the coal shutes, as shown in figure 5. These shutes are cylindrical in form, are made of rolled plate iron, and are 15½ inches internal diameter and 8 feet in height. Owing to the interference of the hammock netting we were compelled to lower the shute 3 feet below the surface of the deck, leaving us an exposed height of only 5 feet, and only this height is effective for draught. When these shutes were secured in position it was found that a light breeze abeam would cause a downward current in the lee chimney and a strong upward current in the one on the weather side, no doubt from the deflection of the air from the slanting surface of the hammock netting. But when there was no perceptible wind there was an upcast draught in the coal shute as well as in the permanent chimneys over the engine room, ward room and shaft alley.

On the 2d of August I suspended a thermometer inside the coal shute, and another near the top, in the external air, the former indicating 87.6° Fahrn.—the mean of a number of observations—and the latter 84°, the difference being 3.6 degrees: and a number of readings of the anemometer gave a corrected mean velocity of 46.92 feet per minute, which gave a total volume of 3,570 cubic feet of air discharged per hour from this simple and inexpensive device. The volume of air discharged from a chimney varies according to the difference of weight of the air inside and of that outside. This was, I believe, discovered by Montgolfier, the inventor of the balloon. He taught that the draught was equal to the velocity of a body which had fallen through a space equal to the difference of the height of two columns of air of the same weight (and of equal base) the one being of the temperature inside the chimney and the other that of the external atmosphere.

Let H = the height of chimney, in feet.

H′ = the height of the heated column of air of equal weight.

T = the temperature inside the chimney.

t = the temperature of the external air.

A cubic foot of air expands 0.0020276 times its volume, on being warmed one degree, so that we have

$$H'-H = H\ (T-t)\ 0.0020276 \quad . \quad . \quad (4)$$

and, consequently, the theoretic velocity will be

$$V = \sqrt{2gH\ (T-t)\ 0.0020276} \quad . \quad . \quad . \quad (5)$$

By substituting numbers for the letters in formula (5) we will find a velocity of 1.533 feet per second, or sufficient to have discharged 6,954 cubic feet per hour, instead of 3,570, as determined by the anemometer. The result recorded is the mean of a number of observations taken when the wind was not blowing, and, as far as could be seen, they were not influenced by any other cause than the difference of temperature between the outside and inside of the chimney. The velocity of the air through the chimney can never reach the theoretic value, for the reason that it is retarded not only by the resistance of the surface of the chimney but by the *contracted vein*, and also by any object upon the lower deck which in any way obstructs the passage of the air to the chimney. I had spent much time in experimenting upon the velocities of air through iron shafts, under varying conditions, with a view to making an empyrical formula for practical purposes, when I found in General Morin's *Etudes sur la Ventilation*, that that distinguished engineer employed a separate experimental value (K) for a co-efficient for each and every shaft. Representing this quantity by K, we have for the correct velocity for our chimney

$$V' = K\sqrt{2gH\ (T-t)\ 0.0020276} \quad . \quad . \quad (6)$$

and in this case the value of K becomes 0.5101.

There are six places in the deck of the Vandalia where these chimneys can be fixed, whereby ($6\times.3570 =$) 21,420 cubic feet of air per hour would be discharged from the sleeping quarters of the men, not only purifying the air on the deck, but reducing its temperature. At the after end of the ward room of the Vandalia there is a copper ventilator 12 inches in diameter and 9½ feet in height. Its lower end is contracted by adjacent wood work, its upper end by an elaborate hood, and near the middle of the shaft it is further reduced in area by a metallic grating. During cool weather, when the ward room was kept much warmer than the external air, the current was quite strong in this shaft. The wind did not seem to increase the velocity of the air, nor did it retard it, owing probably to the construction of the covering. It was effective even in warm weather. On one occasion, while lying in the harbor of Aspinwall, (15th September, 1879,) when the temperature on deck was 80° and in the ward room 86°, I meas-

ured a velocity of 1.405 feet per second, which amounted to a discharge of nearly 4,000 cubic feet of air per hour. This ventilator is over the pantry, and is doubly valuable in removing the odors of that apartment from the ward room. Situated near the ventilator is a similar one which connects with the bread room. As the bread room is ceiled in, and no air can get in to supply the ventilator, it is of no use.

The amount of air exhausted from over the boilers by means of the smoke pipe jacket is considerable. On the 2d December I made an experiment on the Vandalia's jacket (figure 6) the result of which I record:

Date of experiment,	December 2d, 1879.
Total height of the jacket, in feet,	14½
Height of jacket above the dead plate, in feet,	5
Depth of jacket below the dead plate, in feet,	9½
Net area (A) of cross section of the jacket, in square feet,	10.78
Net area between the outer edge of the jacket and the inner edge of the canopy,	9.05
Temperature (T) on deck,	44
Temperature (T′) around the jacket, between decks,	88.25
Mean temperature (T″) surrounding the jacket $\left(\frac{9.5\ T'+5T}{14.5}=\right)$	73
Mean temperature inside the jacket,	87.41
Mean measured velocity of escaping air, in feet, per second,	3.736

By substituting this experimental velocity in formula (6), and by transposing and dividing, we have 0.716 for the value of K. In this case it must be remembered that not only the velocity is greater, but the surface, as compared with the area of the ventilator, is enormously larger than in the former example.

The contraction of the outlet of the jacket, by too small diameter of the canopy, probably retards the outflow still more. Yet, under the disadvantageous circumstances, there were in the experiment recorded 145,000 cubic feet of air discharged per hour, or sufficient to ventilate for 63 men. The standing part of the present smoke pipe is 23 feet, and there is no reason why the jacket can not be made the same height. Nor is there any reason why it should not be made 8½ feet in diameter, or nearly the whole width of the boiler hatch, as shown in figure 7.

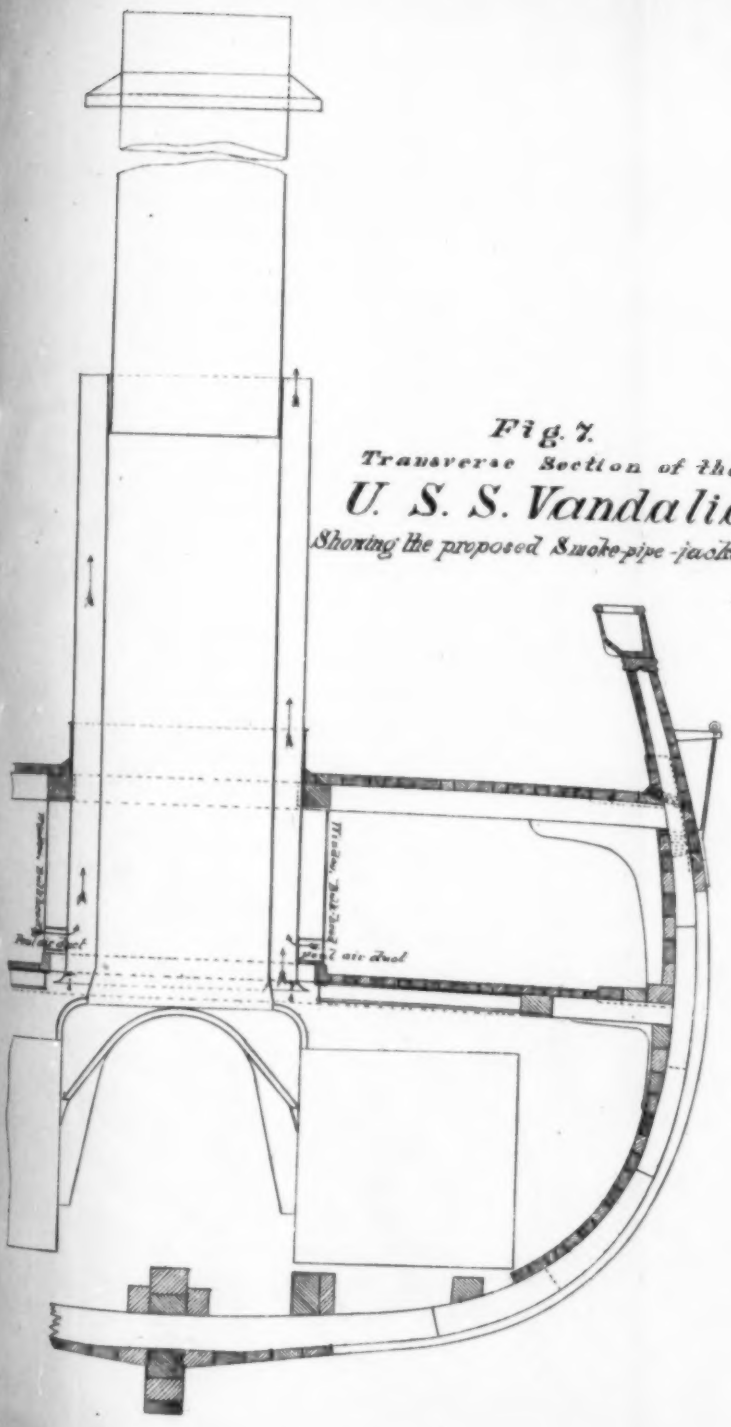
Assuming the conditions to exist as in the previous example, this arrangement would discharge 300,000 cubic feet per hour, or sufficient ventilation for 130 men—the entire number billeted upon the berth deck.

Fig. 7.

Transverse Section of the

U. S. S. Vandalia,

Showing the proposed Smoke-pipe-jacket.



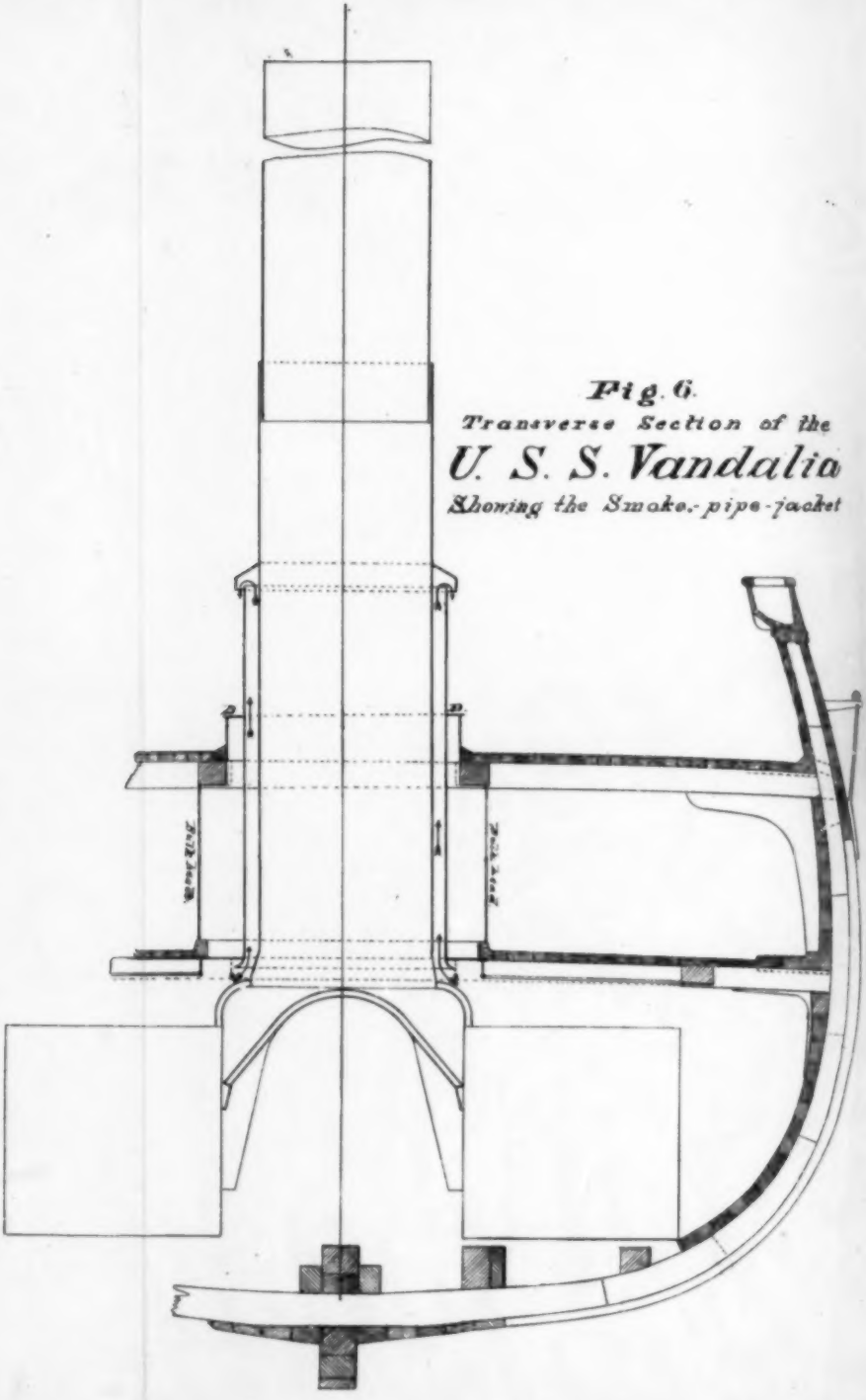


Fig. 6.
Transverse Section of the
U. S. S. Vandalia
Showing the Smoke-pipe-jacket

The only objection that now presents itself to me is that the amount of air drawn into the jacket from around the boilers might rob the furnaces and seriously impede the rate of combustion, and, consequently, the potential power of the engine. In meeting this objection we may introduce air ducts to the jacket, from the berth deck, and then, if necessary, contract the area of the bottom of the jacket.

WARMING.—During cold weather we keep our ships warm partly by steam radiators, and partly by excluding the external air. The opening of doors or sky lights, or the temporary removal of hatch hoods, creates considerable inconvenience to those quartered near them, while those who are located near the steam coils complain of excessive heat. With the whole ship closed up, and but little motion in the air, we find it uncomfortably cold near the sides of the ship and uncomfortably warm near the heaters. On board the Trenton the heaters in the ward room contained nearly one square foot of surface to each 100 cubic feet of space in that apartment, and were sufficient to keep the mean temperature in the ward room at 74°, with the hatches wide open, while the external atmosphere was 30°. Nearly the same condition obtained on board the Vandalia. The area of a heater of this kind designed for ship warming may be safely proportioned by dividing the volume of the apartment, in cubic feet, by 100.

In order to uniformly disseminate heat throughout a vessel we must either have a large number of small heaters, spaced at regular intervals, or warm the air as it enters the ship. The former would encumber the floor, while the latter would require aspirating machinery to make it a success.

Early in December last, when the vessel was warmed by the radiators, and when the sky lights and hatches were closed, Dr. Arthur found 19 parts of CO_2 in the air of the ward room, which, from formula (1), would indicate that only 456.4 cubic feet of air per hour for each of the 12 occupants passed through the ward room. This is about one-fifth of the necessary amount. It appears, then, that, if we supply 2,300 feet per hour to each of the 12 men in that apartment, and if we wish to warm the air as it enters, we must increase the surface of the heaters five fold.

For example, the wardroom contains 7,417 cubic feet, and multiplying this by .05 we have 370.85 square feet required for the heater. The hatch coamings are of iron, and the sky light of the ward room is 5 feet square, in the clear. By putting 2 coils of 1¼-inch pipe inside that coaming, as in fig. 8, employing 16 full convolutions in each, we

can get 200 feet, or half the necessary area in the single sky light. It will then be necessary to encase the whole coil with sheet iron, except at the bottom, and to place inlet holes near the top. It must be added that this form of heater would not work unless an in-current of air be created by mechanism in the ship. It would work admirably on board the Richmond.

I have given fig. 8 merely as an example, and wish to state that I would not, if designing the heaters, place the entire surface in a single hatch, because the velocity of heated air issuing would be too great. General Morin recommends that the velocity of the incoming air should not exceed 1¾ feet per second. It would be more convenient to place a coil in each of the three hatches; and, by having the casing large enough to leave 2 inches on each side of the pipe we could get sufficient area to reduce the velocity to about 2¾ feet per second when the fans were inducing the full amount of air. Of course this could be diminished at any time by slowing down the fan, and that would only be necessary when persons were compelled to sit near the warm air inlet. The advantage of saving the floor room, now encumbered by steam heaters, is of some importance, while the convenience of being able to sit under a sky light to read or write and at the same time enjoy a pleasant temperature will make life on board ship more agreeable.

Moisture.—The hygrometric condition of the atmosphere we inhabit is of almost as much importance as its temperature, or its freedom from poisonous or deleterious gases.

In cold weather the atmosphere is proportionately free from moisture, hence the true time to supply moisture is not when it is warm, as in spring or summer, but in winter, when it is warmed artificially. After securing a sufficient quantity of air its temperature and moisture are of next importance. If cold air be heated in summer by natural causes it absorbs a proportionate share of moisture from the lakes, rivers and the ground, or from the sea, and thus reaches us in a salubrious condition. On the contrary, if cold and dry air be artificially warmed without receiving additional moisture its increased power to absorb moisture renders it offensive.

"Warmed air," says Prof. Wyman, "without increased moisture, is; apt to produce unpleasant sensations in the chest, which are often attributed to too great heat." In cities there is more than four times as much water held in the air at 75° than at 32°, though I doubt if the difference is so great at sea.

Dry air is an active absorbent of water. Many a shower which is

precipitated from a cloud never reaches the ground, and the north winds of Europe, robbed of their moisture in passing over the chilled surfaces of the Alps, are dry and arid when they reach the coast of Africa, where they are re-warmed to a degree far exceeding the dew point, the result of which is the rainless region of the great Sahara.

The relative humidity of the atmosphere is expressed in "percentages of the saturation of the air for moisture at any given temperature." If a cubic foot of air, saturated with moisture, be warmed, its humidity is reduced from one hundred to, say, seventy; and, conversely, if a cubic foot of air whose relative humidity is seventy be chilled, its humidity is increased up to its saturation, when it becomes again one hundred.

For example, on board the Vandalia, on the coast of Syria, in July, 1878, the observed temperature of the dry bulb thermometer was 84°, that of the wet bulb 63°, difference, 21°. This corresponds respectively to 12.376 and 6.361 grains of moisture in the air, or a relative humidity of

$$\left(\frac{6.361 \times 100}{12.376} = \right) 51.3.$$

From Dr. Charles M. Wetherell's report on the ventilation of the Capitol, I copy the following:

TABLE OF THE MEAN PROPORTION OF AQUEOUS VAPORS IN THE AIR OF HALLE, GERMANY.

	Tension in millimeters of the aqueous vapor, measuring absolute humidity.	Relative humidity.
January	4.509	85.0
February	4.749	79.9
March	5.107	76.4
April	6.247	71.4
May	7.836	69.1
June	10.843	69.7
July	11.626	66.5
August	10.701	61.0
September	9.560	72.8
October	7.868	78.9
November	5.644	85.3
December	5.599	86.2

"Thus," continues the Doctor, "as the tension, or absolute humidity, increases with the year, the relative humidity decreases."

The following table* expresses in Troy grains, the weight of vapor

* Guyot No. X, Smithsonian Meteorological Tables.

contained in a cubic foot of saturated air at the different temperatures of Fahrenheit:

TABLE SHOWING THE NUMBER OF GRAINS OF WATER CONTAINED IN A CUBIC FOOT OF AIR AT DIFFERENT TEMPERATURES.

Temperature of the air.	Vapor in grains.	Temperature of the air.	Vapor in grains.	Temperature of the air.	Vapor in grains.	Temperature of the air.	Vapor in grains.
0	0.545	59	5.566	72	8.521	85	12.756
5	0.678	60	5.756	73	8.797	86	13.146
10	0.841	61	5.952	74	9.081	87	13.546
20	1.298	62	6.154	75	9.372	88	13.957
30	1.968	63	6.361	76	9.670	89	14.378
32	2.126	64	6.575	77	9.977	90	14.810
40	2.862	65	6.795	78	10.292	91	15.254
45	3.426	66	7.021	79	10.616	92	15.709
50	4.089	67	7.253	80	10.949	93	16.176
55	4.860	68	7.493	81	11.291	94	16.654
56	5.028	69	7.739	82	11.643	95	17.145
57	5.202	70	7.992	83	12.005	96	17.648
58	5.381	71	8.252	84	12.376	97	18.164

In the West Indies, the relative humidity on board ship frequently reaches 100°, even in summer time; and, during rain storms, when the hatches are covered, the atmosphere below is not only mephitic from the respirations of the men, but is saturated with moisture: there can then be no absorption by the air, consequently the heat is oppressive. But the rapidity of evaporation from the body depends upon the low relative humidity of the air at high temperature and of the action of currents of air. With too great dryness of air, particularly at higher temperatures, and especially in strong draughts, a greater degree of evaporation than is consistent with health will ensue. There is then a happy mean in the relative humidity which is consistent with health and comfort, and for the determination of this point we must look to the surgeons of the Navy, who are now pursuing the subject with increased interest and vigor.

To supply the necessary hydration to the air is an easy matter, and requires but a simple device—an ordinary stop-cock. I do not think water could be used very successfully on board ship, as the spray would necessarily require space that could not be spared; but a jet of steam would do the work most effectively and economically. The experiments, on the absorption of gases by water, made at Mare Island in 1870,* demonstrated very satisfactorily the rapidity with which gases

* Journal of the Franklin Inst., Jan., 1872.

and water, or more particularly air and steam, combine as the steam is in the act of condensing.

TABLE COMPILED FROM THE ATMOSPHERIC OBSERVATIONS ON BOARD THREE SIMILAR VESSELS, DURING THE SAME PERIOD, TWO OF THEM HAVING NATURAL VENTILATION AND THE THIRD HAVING EXHAUST FANS.

		Hartford.	Pensacola.	Richmond.
10 P. M. Observations of January, 1879.	Height of Barometer in inches of mercury,	29.92	30.01	30.13
	Temperatures. Spar Deck. Dry bulb,	68.75	78.00	60.70
	Spar Deck. Wet bulb,	61.72	77.10	56.80
	Berth Deck. Dry bulb,	73.20	83.48	66.56
	Berth Deck. Wet bulb,	66.90	79.37	57.74
	Difference between the spar deck and berth deck,	6.45	5.48	5.86
	Relative humidity on the spar deck,	90.25	94.47	89.02
	Relative humidity on the berth deck,	91.89	94.65	88.68
	Carbonic acid in the air of the berth deck in 10,000ths,	30.30	8.19	10.09
10 P. M. Observations of February, 1879.	Height of Barometer in inches of mercury,	29.90	30.15	29.95
	Temperatures. Spar Deck. Dry bulb,	71.15	70.25	48.00
	Spar Deck. Wet bulb,	65.35	67.40	45.00
	Berth Deck. Dry bulb,	74.17	77.45	53.60
	Berth Deck. Wet bulb,	68.38	72.80	48.20
	Difference between the spar deck and berth deck,	3.02	7.20	5.60
	Relative humidity on the spar deck.	91.22	92.83	83.92
	Relative humidity on the berth deck,	92.21	93.37	85.24
	Carbonic acid in the air of the berth deck in 10,000ths,	10.25	7.676*	10.80
10 P. M. Observations of March, 1879.	Height of the Barometer in inches of mercury,	30.02	30.05	30.10
	Temperatures. Spar Deck. Dry bulb,	69.44	62.17	65.10
	Spar Deck. Wet bulb,	62.78	59.32	59.00
	Berth Deck. Dry bulb,	76.60	72.82	72.84
	Berth Deck. Wet bulb,	66.43	67.01	66.20
	Difference between the spar deck and berth deck,	7.16	10.65	7.74
	Relative humidity on the spar deck,	90.50	97.59	89.30
	Relative humidity on the berth deck,	91.39	92.02	91.60
	Carbonic acid in the air of the berth deck, in 10,000ths,	9.196	6.745	17.54

* 2.76 on the spar deck 27th of February.

THE FIRE ROOM. The temperature of the fire rooms of our ships frequently rises to 120°, and in some cases has reached 150°. This heat is communicated to that part of the berth deck adjacent to the fire room, and that part of the berth deck which surrounds the boiler hatch is particularly uncomfortable as sleeping quarters. You have only to press your hand against one of the panes of glass in the bulkhead to satisfy yourself of the amount of heat that must pass through. The bulk head proper, the coamings and the deck, being of thick wood, conduct the heat very much slower than the thin glass, but, having a great capacity for heat, retain it a long time after the fires are extinguished.

The length of the boiler hatch is considerable; and, to preserve the strength of the vessel as much as possible, the deck beams are carried across the hatch, reducing the area considerably, and not only diminishing the supply of air to the fires but hindering the escape of the

heated air and gases, for both up and down currents exist in the boiler hatches. To correct these evils I would suggest that double windows be substituted for the single panes now used in the bulk-head of the boiler hatches, which will reduce the conduction very much. The wood work of the deck over the boiler as well as inside the bulk head may be covered with a non-conductor such as asbestos. The smoke pipe jacket may be made of greater diameter and height, (fig. 7,) and the deck beams might be made of iron instead of wood, which would reduce their size and obstruction to currents very much. A practice antagonistic to ventilation is to cover the boiler hatch immediately around the smoke pipe with a thick cast iron dead plate, which prevents the escape of the hot air which always surrounds the smoke pipe. In designing these things we have kept in a beaten path, and it is now time to amplify them. Fig. 6 is a transverse section of the Vandalia, showing the uptakes of the boiler, the smoke pipe and the jacket, as they exist. At D the dead plate is shown which supports the jacket. The arrows indicate the natural direction of the current of air. On the top of the jacket (fig. 6) is shown the canopy, or umbrella, as it is sometimes called, the object of which is to keep out the rain, and also to give a finish to the jacket; but as this device retards the outflow of the heated air it needs to be modified.

Fig. 7 represents a similar section of the same vessel, showing the jacket enlarged, as I would propose it, with the canopy riveted to the moving part of the pipe, instead of the standing part, as in fig. 6, and the canopy is so placed as to cover the jacket only when the pipe is lowered.

THE MECHANICAL MEANS OF VENTILATION ALREADY INTRODUCED INTO THE NAVY.—*Beaumont's Exhaust Fan.*—The first attempt at ventilation in the Navy, by any kind of machinery that I have any knowledge of, was made by Lieut. (now commodore) J. C. Beaumont, in 1853.

Lieut. Beaumont's arrangement was an exhaust fan, and was applied exclusively to the magazines of vessels. In 1856 he constructed one, in the New York navy yard, for the frigate Wabash (to which vessel he was attached), and it worked "to the entire satisfaction of all hands." It was used during the entire cruise, and received a favorable mention in a paper by Medical Director R. T. Maccoun, in 1858. "My ventilator," continues Beaumont, "was in use on board the Wabash as late as 1863, having been used on board that vessel during three successive cruises."

Beaumont's ventilator was an ordinary rotary, centrifugal fan, but he connected the pipe to the center opening, making it an exhaust fan, and by running the pipe into the magazine he kept the air there quite fresh, requiring but two men to turn it. The following is a copy of the official correspondence concerning Beaumont's ventilator:

NAVY DEPARTMENT, 10 May, 1853.

CAPTAIN H. PAULDING:

Your letter of the 5 inst., with a report of the cost of the air pump made under the direction of Lieut. J. C. Beaumont has been received. You will be pleased to have the air pump examined by a competent board of officers, and its merits tested, and report to the Bureau. Yours, &c.,

W. B. SHUBRICK.
Chief of Bureau.

NAVY YARD, WASHINGTON, May 11, 1853.

GENTLEMEN:

You will be pleased to examine the air pump made in this yard, under the direction of Lieut. J. C. Beaumont, and have its merits tested, and report the result to me in writing.

Very Respectfully,
H. PAULDING, *Commandant.*

Com'd'r S. H. POWELL,
Lieut. E. G. TILTON,
Master C. V. MORRIS.

NAVY YARD, WASHINGTON, 12 May, 1853.

SIR:

In obedience to your order of the 11th inst. we have examined the air pump made in this yard, under the direction of Lieut. J. C. Beaumont. We believe it will be very useful in our men-of-war and merchant vessels, and to answer all the purposes for which it is intended. Very Respectfully, &c.,

S. H. POWELL, *Com'd'r.*
E. G. TILTON, *Lieut.*
C. V. MORRIS, *Master.*

Beaumont's system was then adopted by the Navy Department, but in erecting the machines the pipe leading to the magazine was led, no doubt by mistake, from the discharge side of the fan, making it send a blast into the magazine instead of exhausting the foul air from that apartment, thus making the machine do the opposite to what the inventor intended. Workmen continued to erect and connect the magazine ventilators on the forced blast principle, and Beaumont's invention, system and labors were soon forgotten.

The Monitor.—The next essay was in the little iron clad steamer Monitor. During her encounter with the Merrimac the crew suffered from

the effects of ill ventilation, and the vessel was subsequently taken to Washington, where the Chief of the Bureau of Steam Engineering, (Mr. Isherwood,) improvised an apparatus which worked very well. He caused a rotary blower, (a Dimpfel blower, I think,) which was in store at the yard, to be put on board the vessel, as near amidships as possible, leading pipes from the after half of the vessel to the suction side of the blower, and discharging the air into the forward half of the ship. He built his conduits of light sheet iron (galvanized, I believe,) and had small registers at intervals for the admission and discharge of air.

The Later Monitors.—In the Monitor ships that followed the original vessel by that name a forced blast was employed. It is the same method as employed in the Capitol at Washington, and in large buildings generally. Why Mr. Erricsson, the distinguished engineer who designed those vessels, preferred that system I am not prepared to say; and, though I prefer the opposite system, I am glad to acknowledge that the ventilation of those vessels is measurably good.

The Despatch.—In 1874, the Secretary of the Navy, having made a voyage on board the Despatch, found the air in the cabin very bad. He accordingly gave the Engineer-in-Chief of the Navy an order to devise some means to ventilate the cabins. Mr. W. W. Wood was then Chief of the Bureau of Steam Engineering. He called Chief Engineer Robie and myself in consultation in this matter, and we visited the Despatch which was then lying at the Navy Yard. We found on board a rotary blower for creating an artificial draught in the boilers, so that we had only to arrange for conduits under the floor, connecting to the suction side of the blower, (a rotary fan,) and to provide registers which we placed in the floor. This arrangement has worked very well, changing the air rapidly without making a strong draught.

The Richmond.—In March, 1878, the Secretary of the Navy appointed a board, consisting of medical inspector T. J. Turner, commander J. R. Bartlett, chief engineer David Smith, and constructor B. E. Fernald, "to examine and ascertain the best system of ventilation by mechanical means or otherwise," etc., etc.

The board recommended that the system of ventilation by aspiration be adopted, and that the most approved exhaust fans with independent engines be employed. This is essentially what had been done in the Monitor and in the Despatch, so that the Richmond is the third vessel in the Navy ventilated on that system. The Board explained

in their report a plan of the conduits, where they were to lead, *et cetera*, and where and how they should receive and discharge the air. The Richmond was designated to receive the mechanical ventilation, and it was placed on board at the Boston Navy Yard during the year 1878. The exhaust fans required were larger, I believe, than any regular merchantable size, and the patentee, Mr. Sturtevant, designed and built those two especially for the Richmond, with the engines bolted to the frames of the fans, and connected directly to the fan shafts. The chief engineer of the Richmond reports favorably on the smooth working of the apparatus, and states that while they are in use there is no smell of bilge water gases, and that the washed decks are soon dried by the rapidly passing currents of air. But the analysis of the air of the berth deck, from specimens collected at 10 P. M., while the men are berthed, as reported by the surgeon of the vessel, indicate very little improvement over the Hartford, (a sister ship) for the same period, and the air on board the Richmond was not as pure as that on board the Pensacola (a sister ship) during the same period.

The purity of the external atmosphere, of course, has a great deal to do with this, as has, also, the opening of the air ports, and the employment of wind sails. I think the better method of testing the efficiency of the Richmond's ventilation would be to institute a series of experiments on board that vessel, taking a large number of specimens of the air simultaneously, for analysis, both with and without the exhaust fans in operation and with the men in their hammocks ; and it would be well at the same time to analyze the external atmosphere for carbonic acid.

In 1876 chief engineers Newell, Robie and Dungan were appointed to devise the ventilating machinery for the Miantonomah, which vessel was then being rebuilt. The ventilating machinery of the original vessel was designed by chief engineer Isherwood, and consisted of rotary blowers situated under the turrets and driven by steam engines through the intervention of belts. The blowers were not arranged to exhaust. On the 29 June, 1876, the Messrs. Newell, Robie and Dungan submitted their report, which was adopted.

The system devised and now in use on board that vessel is novel, inasmuch as the fans are reversible, i. e., by shifting the valves in the blower openings the fan changes from a blower to an exhaust fan. These fans, which are 7 feet in diameter, are intended to be run up to 500 revolutions per minute, with a capacity of 20,000 cubic feet of air for each, or 40,000 cubic feet for the two machines.

They are driven by direct acting engines, bolted to the blower frames, (fig. 9,) * and are arranged under the turrets (fig. 10).

The duty of the blower will be to supply air to the furnaces, as well is to ventilate the ship. The furnaces are intended to burn 5,000 pounds of coal per hour, which will require ($5{,}000 \times 24 \times 0.075 =$) 9,000 cubic feet of air. Deducting this from the capacity of the fans at 500 revolutions, $40{,}000 \times 60 = 2{,}400{,}000$ we will have (2,400,000—9,000 =) 2,391,000 cubic feet left. The complement is intended to consist of 34 officers and 285 men, or a total of 319 people: therefore the amount of air allowed is $(\frac{2{,}391{,}000}{319}) = 7{,}495$ cubic feet each individual. The engine power to drive these blowers up to 500 revolutions per minute is more than ample.

The CHAIRMAN:—When it is proposed to consider the various methods proposed for the ventilation of ships the forms of apparatus can be grouped for the purposes of study under three classes:

1st. Those that take the air out, or act on the Vacuum principle;

2d. Those that force the air in, acting on the Plenum principle; and

3d. A class composed of a mixture in varying degrees of the first and second classes. These are here considered in the opinion of your chairman to be grouped in the order of their frequency, usefulness and efficiency.

It is not proposed to consider at this time the necessity that exists for pure air on ship-board—air at least of the purity of that on the spar deck—nor to show by scientific mathematical demonstration the quantity required by the individual or demanded of masses of men, considering the surroundings when in enclosed spaces, nor to demonstrate to you from statistics the disease producing influence of impure air; for it is known to you all that the necessity for pure air is the constant iteration of every sanitary observer. Very slow has been the progress in the direction of practial application of the means for securing proper ventilation below the spar deck, although, as I shall show, the appliances proposed are numerous.

Of the first class of apparatus those that take the air out of a vessel are the most numerous as well as the most efficient. The removal of a volume of foul air is followed immediately by a volume of fresh air, impelled by the *vis-a-tergo* of the air, almost always a constant dependent, of course, upon barometic pressure.

It follows in this method that the mean change from a static (i. e. the air below deck) to a dynamic (i. e. the external air) condition makes the static head almost a dynamic one, and so merges this class into the second, or that class of apparatus which forces the air into a vessel.

This class has always a *vis-a-fronte* element to deal with, which will vary according to circumstances from a zero of resistance until even P (pressure) will = R (resistance) and the ventilation = 0.

These remarks are applicable to air circulating in tubes. The element of friction of the air in conduits has not here been considered. Those who are interested in such subjects are referred to the work of Peclet.

Of the third class there are too few, and reference will be made to them hereafter.

Under the first class are to be grouped exhaust fans, bellows, tubular and the automatic systems.

* From the report of the Engineer-in-Chief for 1879.

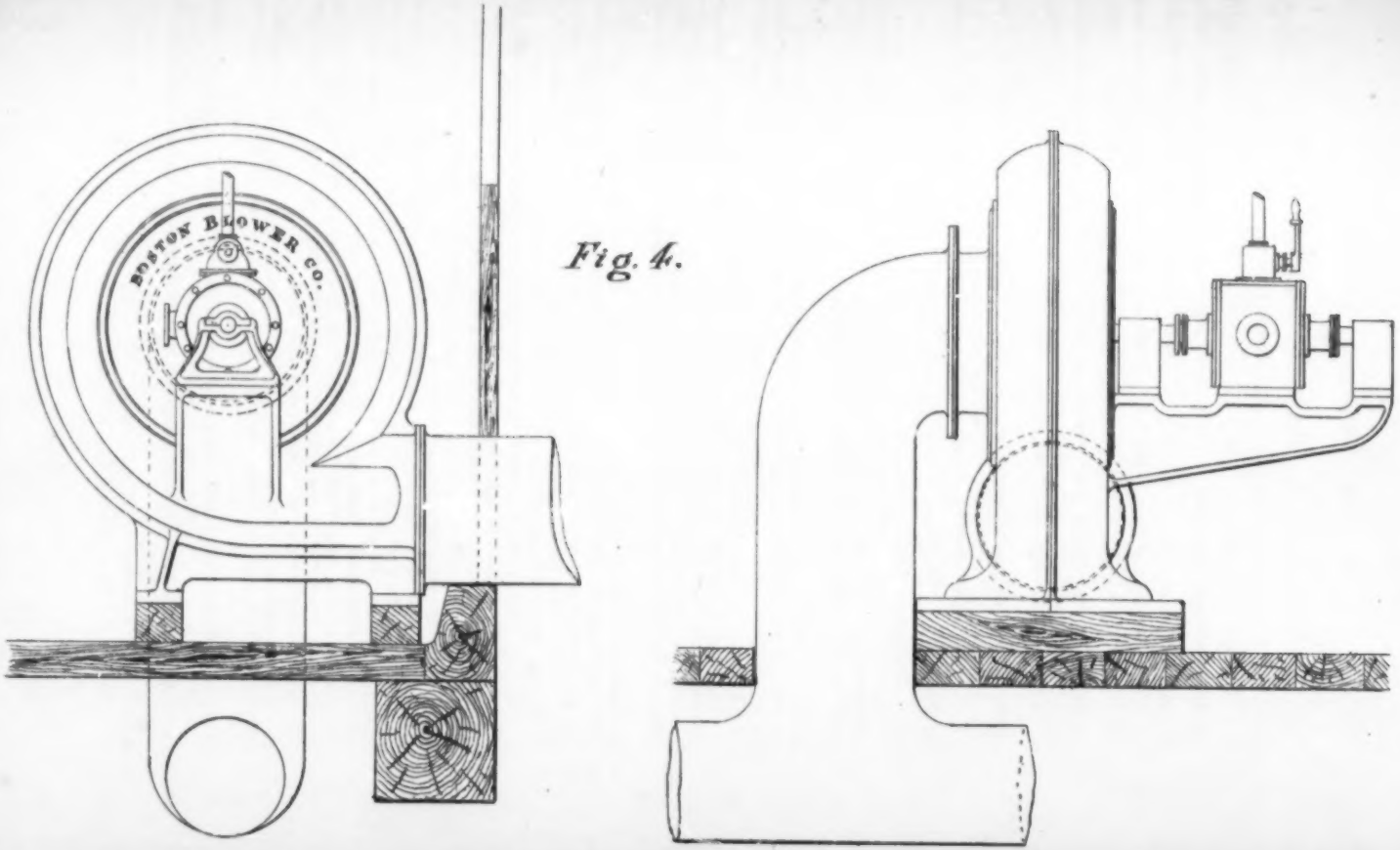


Fig. 4.

Under the second class the means used are, windsails, cowls, shafts et cetera.

And under the third class are to be placed the various fans reversible in action so as to act on either the vacuum or plenum principle, air-ports, et cetera.

I may here make the statement that the presence of a hatch does not exert much influence in an apartment otherwise closed.

Under such conditions there is about as much ventilation as in an uncorked bottle, for it has been stated by an eminent scientific ship builder that "the influence of an ordinary hatch to an otherwise closed hold is not felt much beyond a radius of eleven feet."

To those members of the Institute desiring to pursue the subject I respectfully offer this short résumé of authorities who have proposed methods for ship ventilation, or adopted suggestions of others having direct bearing upon this matter.

Agricoca—De Re Metallica—describes a mechanical apparatus for ventilating mines by injecting air with a rotatory fan, thus anticipating De-Sagulier, Commodore Beaumont, and Brindjonc apparatus for ships.

In 1664 Dr. Henshaw, in his book called "Oerochalinos" published in Dublin, adopted one of Boyle's speculations, using a bellows to pump air in or out of a room. This was an anticipation of Commodore Barron's patent in 1835 for pumping the air out of a vessel by means of a smith's bellows.

In 1723 De Sagulier invented his wheel; and in 1741 Hales invented his "Ship's lungs," which in some measure resembles the apparatus of Henshaw.

At this same date comes the persistent, undaunted brewer, Samuel Fulton, assisted by his friend Dr. Mead, with his Thermo-ventilating apparatus.

Sutton published an "Historical account of a new method of extracting air from ships," which, with slight alteration of dates, would almost apply to the present time. In 1741, also, Sir Martin Triewald, a Swedish engineer, invented a machine to draw bad air from under the decks of the Swedish ships blockading St. Petersburg, and in 1742 his method was adopted by the French. I have not been able to obtain a description of this apparatus.

Of the French inventors, Du Moncean, Wittig and Wazon have suggested Thermo-ventilators. Damboise, Nouahier and Giffard propose cowls. De-Cante (1870) suggests a method by compressed air. Of the others proposing means for securing the ventilation of vessels, I may mention Villiers, Kerauden, Brindejonc, Iouchon, Simon Defaix, Peyre, Ichiele and Williams, Poisenille (1846), Mondesir (1869) and Beaumaoir (1875).

To these already mentioned of English inventors must be added, Boyle and Arnott, whose method with variations, the principle remaining the same, has found its exponent in the hollow masts of the Spartan. Edmunds, 1865, by aspirating tubes; Dr. J. D. MacDonald, Prof. Naval Hygiene at Netley, Dr. Harry Leach, and the Napier system, as it is called, which the speaker of this evening modified in some particulars, in 1873.

Our own countrymen have not been idle in this direction. Commodore Barron, in 1835, McDonald 1841, Knight, 1847, Emerson, 1848, Robinson, 1850 and 1854, Bulkley, 1850, Sexton and Ennis, 1851, Thompson, '54, Bahr, '55, Knecht, '56—'58, Covel, '64, Burnett, Wells, and Woodward in '65, Wheeler, '67, Vanderbilt, '69, Sampson, '71, A. W. Thompson, '73, Jones, '76, Keating and Yaum in '78, nor must I omit the apparatus of Sir J. Liston Foulis in 1879, nor the cowl of Dr. Owens, U.S.N. nor Dr. Gibbs, U.S.N., modified wind-sail.

Of the Automatic variety of apparatus I may mention those of Thiers and Roddy 1871—1877, Delano U.S.N., '78, and Norton 79.

Of the inventors of modified air ports there must be noticed Sinclair 1864, Fernald, U.S.N. '77, Wilson, U.S.N. '79.

It is said that chief engineer J. W. King proposed a plan for ventilating

vessels in 1859, and chief engineer Isherwood has reported (1879) upon a plan proposed by D. C. Green, Esq., of N. Y.

As to the system of mechanical ventilation in the vessels of the monitor variety it is too well known to you all to demand more than this recognition.

The tendency at the present time is almost entirely towards the methods of the first class—extracting the air from the vessel, and in the course of some observation and a good deal more study, I give my adhesion, under the usual reservations upon scientific matters, to those methods.

One more statement in conclusion. To-day I have reason to know that two of our vessels are well ventilated—the Richmond and Lancaster. Of my share in this advance it does not become me to speak. I have the satisfaction, however, of knowing that there has been secured to some of my mess and ship mates, and I trust in the future will be secured to all my fellow-officers, the extinction of the remembrance of the foul and "stuffy" atmosphere of a berth deck by a liberal supply of pure air. One side of the naval sanitary triangle has been drawn—Ventilation—the other two, cleanliness and dryness, must soon be limned. When completed, health and its attendant comfort, as elements of an increased efficiency, are secure.

Medical Inspector GIBBS. I fully agree with the main feature of the instructive address to which we have listened this evening, and hope that the practical points may be adopted in our service, as fast as vessels are built or repaired. That we are sadly behind in our labors, in securing the practical advantages of ventilation in our ships of war is a most humiliating and painful fact. Having already written and labored somewhat extensively in this field I will confine myself to supplementing the speaker's remarks by describing the peculiarities of the fire-room hatch of H. M. Ship "Volage", which I visited on the south Atlantic station.

This hatch, between the berth and spar decks, was unincumbered with bulk heads, and the spar deck hatch was dedicated to aiding the ventilation in this part of the ship. In order to describe it intelligibly, the fire room hatch on the berth deck may be imagined to be divided into three parts. The central part comprised about one half of the area of the whole hatch, and, of course, included the smoke pipe etc. The two ends of the hatch, comprising about the other half of the hatch, were open spaces. The central half was covered with iron, sloping from a point about on a level with the spar deck, down to the quadrangular coaming, where it was secured. In fact this covering resembled an inverted hopper with the smoke pipe passing up through its centre. In this situation there was no obstruction to the passage of air through the spar deck of the hatch, and one half of the corresponding berth deck hatch was open to the descending current, where an upward current was forced beneath this hopper arrangement around the smoke pipe.

The officers of the ship informed me that there was never any annoyance experienced on the berth deck on account of the escape there of gases, ashes etc. The automatic ventilation of ships, I would add, by any aspirating device which we now possess, depending upon the force of winds or waves, has not, in my experience, been marked by any satisfactory result; and I would urge in the name of every hour I have lived in a vessel of war, and of every page I have read, endorsed by every conclusion I have reached in much reflection upon this subject, that a ship shall never be commissioned which is not provided with such a system of mechanical ventilation as now exists in the Richmond, or its equivalent.

Lieut. J. T. SULLIVAN: I am familiar with several types of automatic ventilators, but there is one form which I have had in use at my home for some time, and in studying its usefulness there I have been led to think that it might be applied with equal success on board ship. The ventilating apparatus or "cap" consists of four principal pieces; the dome, collar, band and tube. The collar encircles the upper extremity of the tube, and while

rising above the tube increases its diameter, becoming bell shaped. The dome has a diameter across its mouth or base equal to the greatest diameter of the collar, and when in place it is supported a short distance above and directly over the collar, leaving an opening all the way around between them. The band is somewhat broader than this opening and of greater diameter than the collar, so that in position it encircles the opening but does not come in contact with the main structure except at the points where it is secured.

In operation the "cap" works as an aspirator, and the external air currents, no matter in which direction they move, whether vertically, diagonally or horizontally, produce a tendency to vacuum in the tube, and consequently an upward and outflowing current. This process continues as long as there is any agitation of the external air, and the velocity of the exhaust current is increased as the wind increases. Applied to an apartment, its tendency to exhaust the air creates the desired circulation.

The correct principle of ventilation being to supply means for lifting or pumping the impure air out, as then fresh air will take its place, it would seem that the device described is well adapted to accomplish this process. Fitted to a vessel, in suitable sizes for the different locations, they would occupy, and with proper connections, they would insure an almost continuous circulation through its holes, bilges, store rooms and apartments. In selecting situations for them, advantage can be taken of their power to act whether they are placed right side up, up side down or sidewise; and for this reason they could be run along underneath the hammock rail, on the outside of the ship, and project only a few inches. These would serve to ventilate the holds, bilges, *et cetera*, while others of greater capacity could be distributed about the decks, and one of sufficient size to cap the smoke stack would do good service, not only in the process of ventilation and in exciting a strong draft for the fire, but in protecting the interior of the smoke stack and its dependencies from the weather.

P. A. Eng. ROELKER: Mr. Chairman, I wish to call attention to that portion of Mr. Baird's paper which gives an account of experiments made by him on the velocity of air currents in ventilating shafts temporarily fitted to openings in the deck. These experiments show how large a quantity of air may be discharged through such improvised air ducts, or by making use of the annular space between the chimney and its outer casing, as proposed by Mr. Baird, when the temperature below decks exceeds by but a few degrees the temperature of the outside air. Such means of ventilation are, of course, purely auxiliary, and are not intended to take the place of systematic mechanical ventilation; but, in the absence of the latter, means may be found in nearly every vessel for improvising temporary ventilating shafts which will exhaust large quantities of the vitiated air below decks. Since the majority of our naval vessels will remain, necessarily, without mechanical ventilation, for years to come, it is to be hoped that the facts presented by Mr. Baird will induce others to apply in a similar manner the means at hand to the ventilation of our vessels, and I have no doubt that Mr. Baird will feel rewarded for his labors if the interesting paper read by him tonight produces this immediate practical result.

Lieutenant TANNER: It will, perhaps, be of interest to those present if I give a short account of my own experience with ventilators in sea going ships. When I took command of the Pacific mail steamer City of Peking, I found that she had been fitted with ventilating apparatus which extended to all parts of the ship except the main passenger saloons, which, being light and well up above the water, where air could circulate naturally, were considered not to require artificial ventilation. The draught was furnished by large blowers in the fire rooms, connected to circulating pipes, having at proper intervals small ports fitted with shutters. Particular attention had been paid to the ventilation of the cargo and passenger decks; the latter requiring a very frequent change of air, owing to the number of Chinese

that were transported each trip. On my arrival in Yokohama on my first trip I found a couple of Italian merchants who were in great trouble with regard to the transportation of a heavy invoice of silk-worm eggs. Hitherto the Pacific Mail company had refused to take this sort of freight, on account of the risk of losing a great part of it on the long passage to San Francisco. It is absolutely necessary that silk-worm eggs shall be kept in a cool place, where air can circulate freely about them; otherwise, if the temperature rises above a certain point, the eggs will hatch and the cocoons are spoiled. Having tested the ventilating apparatus thoroughly on the trip, I was very confident that it fully answered all that could be required of it. I therefore made overtures to the merchants, and succeeded in underbidding rival lines, and secured the cargo, which was valued at over half a million of dollars. This cargo I transported with absolute safety to San Francisco. Every morning on my round of inspection through the ship I would start the blowers and open the connections on the cargo deck, and in twenty minutes I could bring down the temperature 10°. It was only necessary to ventilate for about ten minutes three or four times in the twenty-four hours, and the temperature of my cargo would be kept at a constant point. Thus in one trip this apparatus paid a dozen times over the cost of putting it in the vessel. The Chinese passengers were frequently very much annoyed by the draught when their bunks happened to be in the vicinity of the ventilating ports, and, as they could not close the shutters, they resorted to stuffing their hats or clothing into the ports. The draught was so strong that no amount of jamming would hold their things in position, and every thing they put in would be drawn straight to the fire-room. Showers of hats, pantaloons and shirts were not infrequent in the stoke hole. Notwithstanding the airy position of the passenger saloons, the lack of proper ventilation was readily noticeable at sea. Passing from one of the ventilated apartments to the saloon, its "stuffiness" was quite appreciable, although, compared with the apartments of our men-of-war, these saloons were extremely well ventilated.

Lieutenant VERY: In going over H. M. ironclad Dreadnought, I was especially struck with the excellence of the ventilating apparatus, which was apparently of the same type as that mentioned by Lieut. Tanner. The circulating pipes ran along under the shelf pieces of the main deck so as to be just above the head, and in the state rooms just over the bunks. The ports, of which there was one to each room besides a number elsewhere, throughout the storerooms, engine rooms, berth deck and holds, were closed by shutters, so that the draught at any one place could be regulated. Another feature noticeable on this ship was the absence of engine room bulkheads. The heat from engine and fire rooms was forcibly *drawn* straight up through the uptake jacket apparently, at any rate it could not distribute itself about the decks. I noticed this same feature on the Russian ironclad frigate Minin, and I also remember that whilst a midshipman on the Asiatic squadron I commented on the absence of fire and engine room bulkheads on the French ironclad Belliquense, remarking that it must be very hot on the berth deck and in the steerages, owing to the escape of hot air. I was corrected by one of the French officers, who told me that on the contrary the deck was better ventilated. This of course was not due to the absence of the bulk head, but to the arrangement overhead by which the hot air was drawn straight up, taking with it the vitiated atmosphere below decks. With our present system of fire room ventilation, cold air is forced down the ventilators and rushes immediately to the fires, leaving the vitiated air to grow and spread itself throughout the ship. Bulkheads are of but little service, as the heat is refracted from their outer surface and vitiates what little fresh air there may be circulating. As for wind-sails, they are simply a God-send to the officer who is able to point the muzzle into his stateroom door. Beyond a small radius their effects are so diminished as to amount to almost nothing.

P. A. Eng. BAIRD: I have had some experience in automatic ventilators, but have never seen the exact device sketched by Mr. Sullivan. We had a very smoky galley pipe on board the Trenton, and it was effectually cured by an aspirating hood which I made on the principle of the air injector which I had previously patented for my distilling apparatus, and which is probably well known to all the gentlemen present. So far as the history of the principles of ventilation are concerned, and to whom the original invention is due, I must admit that I was not well posted, and have, therefore, to thank our chairman for his able chronological arrangements of the dates of those inventions. My part in this matter commenced in 1863, and has been the part of an engineer and not that of an inventor. I have not been able to find recorded the experiments of anybody, except myself, upon the velocities due to difference of temperature in the smoke pipe jacket, nor has any person, so far as I can find, ever attempted to combine the carbonic acid analyses taken on ship board with the experimental draught of the wind-sails, and to put the same to any practical use. Nor is there published, to my knowledge, any data which will guide our mechanics in the proportioning of exhaust fans and tubes for ships. I have viewed this problem from an engineering stand point, and have sought to put it in a practical shape. The paper I wrote on this subject in 1873 (*vide* Sanitary and Medical Report III, Bureau of Medicine and Surgery for 1873 and 1874, and also the Report of the Secretary of the Navy for 1873,) has been favorably received by the officers of the Navy, and I do not hesitate to say that the ventilating machinery on board the Richmond is an indifferent imitation of that proposed by myself.

BOSTON BRANCH.

April 30th, 1880.

Com'dr O. A. Batcheller U. S. N., in the chair.

THE WANT OF DOCKING FACILITIES IN OUR NAVY YARDS.

By Civil Eng. U. S. G. White U. S. N.

Mr. Chairman, and Gentlemen :–

If there is any one thing in which we are deficient in our navy yard appointments it is in the matter of docks. We have not to-day a navy yard at which it can be said that there are any docking facilities.

We have at Boston, New York and Norfolk one stone dry dock each ; at Kittery there is an old and cumbersome lifting dock, as also one at Mare Island. Each of these docks is in bad condition and it was but a short time since that the Mare Island dock failed with a foreign man-of-war, very nearly producing disastrous results. There is now building for the Pensacola yard an iron, floating, sectional dock, two sections being already at the yard. This work being new is probably in good working order and is also, probably, supplied with such appliances as modern requirements may have suggested.

At the yard now building at League Island there are contemplated numerous stone dry docks, and also a lifting dock with marine railways, but it is very doubtful whether any means will be provided for the docking of a ship in such a near future as to interest any one here present. The same may be said of the dockage embraced in the proposed plan of development of the station at New London Conn.

Of all systems of docking it is conceded that the stone dock is the best. Although costing more in the first place, it possesses the advantage of greatest economy of maintenance, while, once within it, a ship is subjected to less strain. The most marked disadvantage is that a very limited space is provided in which to work, and during the heated term the men working in the lower part of the structure suffer somewhat from the heat, being almost entirely cut off from any air that may be stirring. Again a stone dock is limited in its capacity ; but as it is not probable that in the future naval vessels will have the great length which

is being given to the merchant marine this is not so great a disadvantage. Circumstances might arise, however, in which we might be called upon to dock a vessel of greater length.

The superintendent of the Leyland line of steamers instructed one of their captains to learn whether or not there were facilities for docking one of their ships in Boston should she meet with any mishap requiring her to go into dock. After making inquiries at the different docks in Boston he called upon me in company with a friend to learn if our dock would take one of their ships, the shortest one of the company's steamers being three hundred ninety-two feet between perpendiculars. It is needless to say that it could not be docked. The sectional docks are unlimited in capacity, but the great requirement, rigidity, is not found. Although means are now employed to obviate this trouble to a very marked extent, still there is much danger to be apprehended from the strains which are liable to be thrown upon a ship, arising from emptying the different sections unequally, and the greater the number of sections the greater the danger to be apprehended.

The balance dock is, next to the dry dock, the least open to the objections offered to the sectional dock, but still it is a cumbersome affair and, like all lifting docks, the cost of maintenance is great. The addition of railways upon which to haul the ship from any one of the floating docks I think injurious. It is almost an impossibility to place a road on a bed sufficiently rigid and level to haul a vessel upon without doing more or less damage to her, although this is the plan proposed by no less eminent an engineer than Captain Eads for transferring ships across the isthmus of Panama. I do not propose to set myself up in opposition to Captain Eads, but were I the owner of a good ship I would want to see how his plan worked with some other person's vessels before I risked mine; with small vessels there is no reason why they should not be lifted and run upon a railway for storage or repairs, but for large vessels I must say, that I do think there is danger of racking and twisting them.

There is a system of dockage now in use at Nicolaieff in the Russian dock yard, which, in my opinion, is the best yet devised. It possesses the advantage that at almost a nominal cost it can be extended as far as the requirements of the service may dictate. This system consists of a lifting dock of peculiar mechanism and a series of piling, arranged in clusters, upon which the vessel is deposited. The dock is a large rectangular box thoroughly trussed and braced, to which is rigidly attached a number of pontoons also completely trussed; the entire structure being built so as to make it as rigid as possible. On the

side of the rectangular box opposite the pontoons is placed a counterpoise very ingeniously designed. The pontoons are so arranged that the dock can be hauled in against the piling, the pontoons passing in between the clusters of piles. In docking a vessel, a cradle very strongly braced to add to the rigidity of the structure is placed upon the dock, and the whole is sunk; the ship is then hauled over the dock and placed in the proper position, the pumps are started, the pontoons emptied and the vessel lifted, the dock is hauled into the piling, the pontoons slowly filled, causing the dock to sink leaving the vessel in its cradle resting on the piles, and in position for any repairs or work to be done. When a ship is ready to be put afloat the dock is sunk, and hauled in under her, the pontoons emptied, the vessel lifted from the piles, and her cradle hauled out, the dock sunk, leaving the vessel afloat. When a vessel is built she is started and completed in a cradle, and, when she is ready to put afloat the dock is called into use, and she is floated as above described, thus avoiding all danger of straining her in launching,—should it become necessary to dock a vessel when all the space is occupied, all that is required to accommodate her is to drive more piles, brace and cap them, and they are ready for use.

Mr. Clarke, the engineer who built the dock, took every precaution to make the risk to a vessel, while being lifted, a minimum. In testing this dock a vessel was lifted and floated twice in a violent gale of wind, and the action was in every way highly satisfactory. By this dock and its piling the Russian Government obtained, for an expenditure of £200,000 sterling, facilities equal to twenty ordinary stone docks, each one of which would have cost at least, $ 1,000,000.

For the purpose of laying up vessels not required for service this system is very superior, both the time necessary to lift and deposit a vessel and also that consumed in floating her again being very small, while space on the water-front, not otherwise required, can be prepared and used for this purpose.

I will now lay before the institute an idea for which I claim originality, not in the means used but in the application thereof. A dam of peculiar construction has been in use for some years, in France, in streams which at periods require facilities for slack water navigation. Our government is about finishing one in the Ohio river at Pittsburg. The peculiar feature of this dam is that when there is a good boating stage of water, and there is no need of the locks for the passage of vessels it lies flat on the bottom of the river; but when the water becomes so low that navigation is impeded the dam is raised up in short sections, and the water held back, and vessels pass through the locks,

I think only two men are required to set the dam up, a section at a time; when there is a rise in the river the top of the dam buoys up, the props are pulled out from the sockets in the apron, and the whole structure is laid upon the bottom. This action is automatic.

While studying this dam and its working I conceived the idea of applying it to ship-yards for dockage purposes.

I have considered the plan in connection with a wet basin estimated for, located in the site now occupied as a timber basin, between the steam engineering machine shop and the construction buildings near the dry dock. The plan, as recommended to the Secretary of the Navy, contemplated the excavation of the site to a proper depth, I think thirty-one feet, with a lock, which, being connected with the pumps of the dry dock, could be used as a dock for such work as cleaning bottoms and making slight repairs.

To carry out my ideas I would pile a portion of this basin, if not the whole, and put in a heavy concrete floor; attached to this floor will be structures built on the principle of the dam, enclosing spaces suitable for landing vessels on the floor; there will be also cross dams allowing the use of a longer or shorter portion as needed. Ordinarily these dams will lie upon the bottom of the basin out of the way of any vessels to be moved from one part of the basin to another,

When it is necessary to expose the bottom of a vessel the following course will be pursued. She will be put in a cradle and taken to that part of the basin where she is to be landed, the sections of the dam enclosing the space will be raised and secured in place, the pumps will then be started; before the level of the water within the enclosure shall have been lowered sufficiently below that without to throw an under strain upon the structure the vessel will have been landed, and the introduction of shores will have commenced; and by the time the enclosure is pumped out the shoring will have been completed, and the vessel will then rest in perfect safety. I have not worked up the details of construction of the sides I would use. The material should be wood with copper fastenings, and the walls being double, so connected that when lying on the bottom they would come together, but when lifted into place they would be four or five feet apart, with internal toggled bracing which would come into play as bracing when, in raising the walls, they had almost reached the point at which they are to remain. Were I going to construct this work in a locality where the teredo abounds I should use iron, unless the experiments now being conducted by the Corps of Engineers of the Army show that the teredo does not attack wood which has been treated by the Thilmany process.

In that case I would prefer the wood, as more lasting. I propose soon to prepare detailed drawings of a work of this nature, and then I will be able to give an estimate of the cost. The estimated cost of the wet basin heretofore submitted for consideration is one million four hundred thousand dollars. I think with an additional expenditure of about one million dollars facilities for docking six vessels in the basin could be provided. Were a vessel docked as set forth there would be no more risk attending the operation than in putting her in a stone dock. The water in the basin being kept at a constant level, through the interposition of the lock, floating platforms and cranes could be used in carrying on the work. Before floating a vessel it would be necessary to thoroughly clean the floor and remove therefrom all chips and pieces which might in any way interfere with the raising or lowering the sections of the walls; for the same reason it would be necessary to allow no surface drainage to go into the basin with material to be deposited therein. With proper care I believe that such plan would, if carried out, prove highly satisfactory, both as to its action and cost of maintenance; and I would have no hesitation in recommending its adoption. As it would be an experiment I would suggest that it be tried with a single compartment at first, and then, if a success, additional compartments could be provided.

Leaving out of the question the class of docks to be constructed, there is no manner of doubt that a large increase of dockage is necessary. The idea of a naval ship-yard with facilities for docking but one vessel is ridiculous, and the very great inconvenience to which this condition of affairs would subject us in time of war is patent to all. Every yard in the service should be able to provide dockage for ten vessels; any variation from that number should be to increase rather than diminish it. There is no other element of dock-yard organization that possesses the importance of this one. Should a necessity arise throwing upon this yard double the amount of work it is now capable of doing everything could be provided and put in operation in thirty days, by simply preparing the beds for the tools, putting them in place, and throwing over them a temporary covering; but instead of being called upon to do any such thing we are prevented from working the yard to its full capacity by the want of docks in which to repair vessels.

In the plan laid down for the development of this yard, and from which there was to be no deviation, five stone docks were provided for. Why they were not built no one can tell, but the omission of four of the five was a very serious mistake on the part of the authorities having control at that time.

It is a trite saying—"in time of peace prepare for war"; and now that Congress is waking up to the condition of the service, and taking initiatory steps looking to the building up of a navy creditable to us as a nation, I think that one of the most important things requiring consideration is to put our yards in condition to maintain the navy in good order for war purposes. We are well provided with shops, machinery et cetera, and what we need is a large increase of dockage, so that we can work the yards to good and full effect.

Comd'r SICARD. I have been very much struck with the economy of the Russian dock, which seems in every way admirable, and especially in point of expense; the only serious cost would be that of preparing one caisson or floating platform. The part attached permanently to the shore should not be very expensive, and is capable of indefinite expansion. The dock to be made by raising and lowering gates (such as is used for dams on the Ohio river) seems sufficiently easy to arrange and could probably be made tight without difficulty.

Hon. R. B. FORBES. I have long entertained the idea that every naval station on the sea coast should have a place for the storage of iron-clads; almost every naval station has rivers emptying near it and it would be perfectly feasible, in my opinion, to utilize fresh water now running to waste in supplying basins, docks or locks or storing iron-clads. I am not ready nor am I competent to say exactly how this should be done; I leave that to engineers. Let me say however that as the sources from which the streams come are much higher than the proposed basins or docks, I can conceive of no mechanical difficulty to prevent carrying out the idea. It would be altogether a question of money, and it will naturally occur to every one that the cost of the docks, and of the supply of water, may be too great to warrant carrying it out.

Perhaps the simplest plan would be to construct a basin for the storage either dry or afloat of three large ships. In time of peace, when movements would be rare, the expense of maintenance would be small, and in action, even if large, the expense would be a secondary matter. I shall not take up your time further than to say that competent engineers may do well to make estimates of the cost and maintenance of the docks. They need not be of fine hammered granite, nor need they be monuments of architectural skill like the dock near by; with strong sea walls and gates they may, I fancy, be built very cheaply, the land being the chief cost.

Civil Eng. WHITE. I would say in reply to Mr. Forbes's remarks on the subject of fresh water basins in which to lay up iron clad vessels that since I have been in the service I have been on two boards of engineers to lay out and prepare estimates for such works, one at Norfolk and the other at the New London station. The one at Norfolk covered twenty seven acres, the estimated cost being about one half million of dollars, including a lock five hundred feet long by eighty feet wide, and bringing water from the Dismal Swamp. The one at New London covered a space of seventeen acres, at an estimated cost of about four hundred thousand dollars. As a means for preserving iron clad vessels from the action of salt water, when not in service, I consider the Nicalaeiff system as the best plan now before the world.

Lieut. BASSETT. Mr. Chairman. I move that the thanks of this Branch of the Naval Institute be tendered to Mr. White for his instructive paper.

The motion of Lieut. BASSETT was adopted.

NEW YORK BRANCH.

May 20th, 1880.

Lieut. W. Mc.C. Little, U. S. N., in the chair.

THE NAVAL BRIGADE

By Lieut. John C. Soley, U. S. N.

Mr. Chairman and Gentlemen.

The term Naval Brigade, as you all know, is applied to the forces of a ship or ships which may be landed for operations on shore, and is composed of infantry and artillery, with their necessary accompaniments. This force may be used for a variety of purposes, but each one involves the possibility of fighting. To do this successfully it is necessary to have (1) organization, (2) skill in the use of weapons, (3) discipline. Beyond all question organization is the first essential. It assigns to each man his part in the great whole, it provides his food, his clothing and his ammunition, it prevents accidents and renders confusion almost impossible. Skill with weapons speaks for itself, and it is worthy of remark that this subject has lately received an impetus which is gratifying. In the matter of discipline and instruction we have the greatest difficulty to contend with. A dislike of infantry tactics, as it is called, is inherent in the sailor, principally on account of the unpractical way in which these exercises are generally conducted. It is quite possible however to make them interesting by making them so thoroughly practical that their usefulness will be readily comprehended. We must teach the men to think and to know the part that each one is to play in the war game; we must make them realize that each man, by acting sensibly, can contribute to success, and that it is his duty to coöperate at all times: if we can do this we shall find that the sailor's qualities of activity, readiness in emergency, and his almost daily habit of facing danger will be the greatest aids in making him an efficient fighter when he is on shore.

I propose to give first, a concise history of the operations of the naval brigade in our service with the results obtained; then a plan of

organization and a system of drill which will make our naval brigade efficient to day. I hope I shall be excused for introducing a great many details, but I do it because they will be found useful, and an officer does not always have the means at hand for obtaining them.

Before commencing I must apologize for presuming to lay down any rules of warfare to be followed, because I have no war experience myself. I can only say that I have consulted what are generally acknowledged to be the best authorities, and have united to their teachings my own experience in conducting these exercises as a matter of instruction and drill.

History. 1813. June 22. Defence of Craney island by a party of one hundred seamen and fifty marines under Lt. Neale of the Constitution.

1813. Oct. 23. The Essex, under Porter, at Nookahevah in the Marquesas, went in to refit, made a station, and engaged in wars with the natives.

1814. Aug. 17. The Adams, under Morris, having been injured by going ashore on the coast of Maine, and a squadron of the enemy approaching, she was taken up the Penobscot to Hampden and an attempt was made to protect her. Batteries were erected on the river bank, and the seamen and marines endeavored to beat off an attack, assisted by the local militia. The latter gave way, and the seamen, *being without muskets*, could make no effectual resistance. The ship was burnt and the men retreated.

1814. Aug. 24. Battle of Bladensburg. The only resistance of any account, made to the enemy's attacks in this battle, was made by the detachment under Captain Barney, of three hundred and seventy seamen and seventy eight marines from the Chesapeake flotilla. The militia gave way entirely.

1814. Aug. and Sept. Seamen and marines under Commodore Rodgers were constantly engaged during these two months in the Potomac and around Baltimore, partly in boats, but most of the time on shore or in forts. (In September occurred the battles of North Point and Fort Mc Henry). They were of course peculiarly fitted for this mixed service, and did good work.

In several small engagements on shore, on the lakes, the Navy gave valuable assistance to the troops.

1822. January. The Porpoise, Lt. Ramage, sent a force of forty men on shore on the north western coast of Cuba and broke up a depot of pirates, after a hot fight.

1823. April 16. * Captain Cassin, commanding the Fox and three other small vessels, landed his men near Cayo Blanco and had a running fight on shore with pirates. Their establishment of five houses was taken and burnt.

1823. July 22. † Attack on pirates near Cape Cruz by the Greyhound, Lt. Kearney, and the Beagle, Lt. Newton. Similar to Cassin's fight in April. Farragut commanded the landing party.

1832. Feb. 6. ‡ Attack on Quallah Battoo in Sumatra. This was an elaborate and extensive operation. Two hundred and fifty seamen and marines and a 6 pdr. were landed under command of Lt. Shubrick. 1st division, Lt. Pinkham, 2nd division, Lt. Hoff, 3d divsion, Lt. Ingersoll, howitzer, Master Totten, marines, Lt. Edson. Four forts taken by assault, and town burnt. This expedition was sent from the United States to punish the Malays for an assault on the American ship Friendship.

1840. July. Landing parties were sent ashore in the Fiji Islands on two different occasions, from the Vincennes and Penobscot in Wilkes' exploring expedition, to punish attacks of the natives. In the second landing the party met with considerable resistance from the natives, who were well armed. The stockade was captured and two towns were burnt.

1846—1848. War with Mexico. It must be remembered in looking at the naval character of the war with Mexico that it was entirely on one side. Mexico had no navy whatever and made no attempt to prosecute the war on the sea: consequently our navy was almost wholly occupied in coast and landing operations. Of course the main feature of the war was Scott's campaign between Vera Cruz and the city of Mexico: the army of invasion broke the power of the enemy, but the army never aimed at conquest of territory: and when the question of annexation came up it was settled largely on the basis of permanent conquest. These conquests, which were of so much importance in their bearing on the question of annexation, were almost wholly accomplished by the Navy. At the outbreak of hostilities, in June 1846, Commodore Sloat was in command of the squadron on the West Coast, and he sailed in the Savannah for Monterey, where he landed two hundred and fifty seamen and marines and took possession, while the

* Am. State Papers, Naval Affairs, 2, 240, 241.

† Am. State Papers, Naval Affairs, 2, 246.

‡ Cooper's Naval History—continuation p. 33.

Portsmouth did the same at San Francisco. He was relieved in July by Stockton, who determined to strike a sudden blow at Los Angeles, where the California legislature was in session, and which was defended by a force of about fifteen hundred men. He immediately issued a proclamation to the people of California, and organized a battalion of volunteers which he put under command of Col. Fremont, but this force did not participate in the capture of Los Angeles. He sailed southward to the port of San Pedro, which is thirty miles from Los Angeles, where he landed three hundred and fifty seamen and marines, with several 6-pdrs. and one 32-pdr. carronade. He then formed a camp and commenced drilling them, and it is worthy of note that he made no attempt to exact the same sort of discipline that is required in the army, but "they were directed to obey a few words of command such as, 'halt', 'march,' 'form line', 'form square', 'charge', and always to keep the same comrade on the right or left. In executing the necessary evolutions in which they were exercised, though all at first appeared confusion, yet every man soon took his proper place, and the most perfect order was immediately obtained." "They saw their Commodore sharing with them all their hardships, partaking their rations and their toils, marching side by side with them, always going ahead in the hour of danger, and they caught with inspiration the ardor which excited him."* The march was accomplished successfully, the enemy routed, and Los Angeles surrendered Aug. 13. It was left with a small garrison and Stockton returned to the north. Late in the fall it was retaken by the Mexicans, and they drove off the men landed at San Pedro which they also took. Stockton returned, took San Pedro and then went to San Diego from which place he determined to march again on Los Angeles distant one hundred and fifty miles. His force, this time, consisted of five hundred seamen and marines, sixty mounted riflemen, Kearney's sixty dismounted dragoons, one howitzer and six 6-pdrs. He started Dec. 29, fought two engagements, and Los Angeles surrendered Jan 10. Resistance was now at an end and a temporary civil government was established. When the time came to settle the conditions of peace the territory of the United States was increased by this immense district, comprising over six hundred and fifty thousand square miles. The conquest may be laid to the credit of Stockton and the Navy.

Other operations on the West Coast.—1846. September. Party

*Life of Stockton, p. 119 et seq.

landed from the Cyane, at San Blas, under Lt. Rowan, spiked guns, et cetera.

1847. September. Capt. Lavalette landed party at Guaymas to resist threatened attack of the place; enemy drew off.

1847. Oct. 1. Fight at Mulejè. Landing party of fifty seamen and marines from the Dale, under Lt. Craven.

1847. Nov. 11. *Capture of Mazatlan by landing party from Independence, Congress and Cyane, six hundred seamen and marines, five guns. No resistance. This was well organized. Commodore Shubrick commanded the squadron and superintended all the details. Mazatlan was occupied, civil government was established, and two hundred and fifty thousand dollars collected in five months.

1847. Nov. 17. Fight at Guaymas. Landing party of sixty-five seamen and marines, under Comdr. Selfridge; enemy defeated.

1847. Nov 19. } † Gallant defence of San José by Lt.
1848. Feb. 4—14. } Heywood, with a small force of seamen and marines. Finally relieved by landing party from the Cyane, under Dupont, after a close engagement.

1848. Jan. 12. Landing party at San Blas, under Lieut. Chatard. Two guns captured.

Operations on the East Coast. 1846. May 8. Five hundred seamen and marines from the squadron under Capt. Gregory, landed and assisted in the defence of posts on the Rio Grande.

1846. Summer and fall. Tampico, Laguna, Frontera, all taken and occupied by landing parties.

1847. March 22-29. Bombardment of Vera Cruz. Principal execution done by the Naval Battery: a battalion of marines marched with the army to the City of Mexico.

1847. April 12. Capture of Tuspan. Landing party of fourteen hundred and ninety seamen and marines and four field guns, under Capt. S. L. Breese.

1847. June 15. Capture of Tobasco. Landing party of eleven hundred seamen and marines, with eleven field pieces under Commodore M. C. Perry. Fatiguing march, and severe engagements. Tobasco was occupied and the naval garrison was constantly engaged in fights with guerillas.

* Cooper's Naval History, Continuation pp. 71, 72.

† do do do do do 74-77.

It may be said that these were small affairs. So they were, in one sense, as compared with a modern pitched battle: but they represent the whole service performed by the Navy during the war, except blockade duty and transport duty. The results were very important and out of all proportion to the skirmishes that took place. All the seaport towns on both the east and west coasts were taken; the blockade of the coast was turned into an occupation, and at all the ports a naval government was organized, a naval officer appointed Collector of Customs, a tariff established and the whole custom's revenue of Mexico, for the time being, turned into the treasury of the United States.

1854. April 4. Combined English and American landing party at Shanghai to protect foreign residents. Sharp engagement with the Chinese.

1855. Summer. Landings and engagements at the Fiji Islands by parties from the John Adams.

During the war of secession landing parties were being constantly used, and did important service, both on the Mississippi and on the coast. It would take too much time to recount them all, and I shall only mention one which was the most instructive and at the same time the most important; and that was the landing at Fort Fisher. The details of this landing party are familiar to all. It was conceived in a spirit of gallantry and from a natural desire that the Navy should gain as many laurels as possible. But while the attack helped our land forces to victory it was most disastrous to the Navy. It failed, not merely because our men were opposed to disciplined troops, but because they were sent with inferior arms to fight against men who were behind intrenchments and who had the best weapons of the time. I will not enter into any details beyond giving extracts from the orders issued relative to the landing, and an extract from the report of the officer in command of the landing.

These extracts will sufficiently explain the failure. "The sailors will be armed with cutlasses, well sharpened, and with revolvers. When the signal is made to assault, the boats will pull around the stern of the monitors, and land right abreast of them and board the fort on the run in a seamanlike way. The marines will form in the rear and cover the sailors. * * * * *. He will first advance with a thin line of sappers, as soon as he can get a ditch deep enough for shelter, the marines will go in thin squads and occupy them. * * * * * * No move is to be made forward until the army charges, when the navy

is to assault the sea or southeast face of the work, going over with cutlasses drawn and revolvers in hand."*

Lt. Comdr. Breeze in his report says—"I can but attribute the failure of the assault to the absence of the marines from their position; as their fire would have enabled our boarders to use their pistols and cutlasses most effectually. By this I would imply the lack of proper organization, it being impossible in the short space of time, on account of throwing so many small squads of men from the different vessels together in one mass, lacking proper company organizations and wholly unacquainted with each other, to secure such organization." From a careful perusal of all the reports, it appears that the fault did not lie entirely with the marines, as they only shared the general panic. It seems almost too much to expect of men that they should march up to a fort in the face of a deliberate fire, with weapons which were only useful in a hand to hand conflict. The bayonet is superior to the cutlass always, because, as a double weapon, a man has more confidence, and properly drilled with the bayonet, even without ammunition, would be more than a match for men with cutlasses. Such a landing should only have been attempted when every detail of organization had been properly perfected, when companies and battalions were formed and with the men properly armed.

Operations since the war. 1867. June 13†. Hartford and Wyoming at Formosa. One hundred and eighty-one seamen and marines landed under Comdr. Belknap and Lt. Comdr. Mac Kenzie.

1868. Feb. 4‡. Assault at Hiogo by Japanese troops on foreign residents. Joint landing of naval forces present.

1868. Feb. 7. and 19‡. Two landings at Montevideo to protect foreign residents.

1868. April‡. Force landed from the Penobscot at Aspinwall.

1871. June 9. and 10§. Attack on Corean forts. Five hundred and forty-six seamen, one hundred marines, seven howitzers under Comdr. H. C. Blake.

1873. May. Landing at Panama. Two hundred seamen and marines, four guns, to protect the railway and American citizens.

1873. Sept. Landing at Panama. One hundred and thirty men and howitzers.

* Admiral Porter's order. Report of the Secretary of the Navy, 1865.

† Report of Secretary of the navy 1867.

‡ " " " 1868.

§ " " " 1871.

1873. Riot at Honolulu. Landing party of one hundred and fifty seamen and marines, and one gatling. This concludes a condensed history of the operations of the naval brigade in our service.

No one can fail to recognize the importance of the work it has performed, and, at the same time, it has been shown how success was always dependent on organization and drill. As long as our presence alone is sufficient to effect our purpose we may, to a certain extent, let them go, but if we are to fight we must not neglect the smallest point which can contribute to success.

Organization. The basis of the organization of the landing party of each ship must be the number of men that can be carried by the boats without overloading them: having fixed upon the total, it is divided into infantry companies, howitzer and gatling crews, and the special details. The infantry companies are carried in the cutters and smaller boats: certain of the larger boats are fitted for howitzers and are generally used for that purpose, although it will be for the commanding officer to decide, in some cases, whether it is better to carry in the boat thirty men as infantry, with sixty rounds each, or a howitzer, whose locomotion is slow, which requires twenty men to manœuvre it, and which has at best only about forty rounds. The landing party is composed of—

One commanding officer, one aide, one officer commanding infantry, one officer commanding artillery. Marines—as many as are allowed. Infantry companies—two officers, forty men, each. Howitzer crews—one officer, twenty men, each. Gatling crews—one officer, twelve men, each. Signals—one officer, one quartermaster, four men, or less. Pioneers—one officer, carpenter, armorers and four men to each company. Field Hospital—one medical officer, one apothecary and four men. Provisions—one pay officer, one pay writer and one man for each company and crew. Ammunition—one gunner, one gunner's mate, one man to each company and crew, one master-at-arms, one ship's corporal, one ship's cook.

The men to form the companies are taken from the gun divisions, and the companies are officered from the divisions to which they belong. In the same way the howitzers are manned and officered from certain divisions, so that the men will find their comrades in drill next to them, and they will be under the officers to whose commands and instruction they are accustomed. The pioneers are selected from those who are used to the tools required, preferably from the carpenter's crew and engineer's force, with the armorer and his mates; the

ammunition, provision and hospital men from the powder division, and the signal men and gatling crew from the navigator's division.

In assigning the details to the boats, care must be taken to keep the men together under their own officers, the howitzer crews being placed in their proper boats and the companies assigned to any two boats that will carry them, with the commanding officer of the company in one boat and his junior in the other, and these two boats are kept together under all circumstances. The special details are assigned as is most convenient, but it is better to keep them together than to mix them up in the other boats. With regard to the marines it has long been the custom to distribute them as sitters in the different boats; this is open to two objections, first, it diminishes by so many the number of blue-jackets in the pulling boats where they are most useful, and it must demoralize the marines by separating them from their own officers, whom they must seek immediately after landing. This plan was adopted in former days because the marines were not taught to pull, and we had no other means of propulsion for the boats; but now we have steam launches which will generally carry the whole marine guard and they should unquestionably be placed in these boats where they will be under the command of their own officers.

When the landing parties of several ships are combined to form a naval brigade, the same thoroughness in detail must be observed. The infantry companies are united in battalions of four companies each and the howitzers into batteries of four guns each. For each battalion and battery a staff is assigned consisting of adjutant, ordnance officer, medical officer and pay officer, from those furnished by the different landing parties, so that the organization of each unit will be complete. These details should all be perfected before the boats leave their ships, and published to all, so that every officer and man will know his station and his own duty, and will know exactly all who are associated with him. Every boat which is used is numbered or lettered, the letters being used for howitzer boats and the numbers for the infantry and other boats. When organizing the force from a single ship the boats are numbered according to the force, but when landing the naval brigade, numbers or letters are assigned by the commanding officer of the expedition according to the organization.

Equipment. The officers wear undress and leggings, and carry sword, revolver, haversack, water bottle, pocket book, knife, spoon, cup and blanket rolled, containing flannel shirt, stockings and towel. Weight of sword and revolver, 5 lbs. 5 oz.

The marines wear undress uniform with leggings. Knife with laniard, canteen, haversack, tin cup and spoon, blanket rolled, containing shirt, stockings and towel, rifle, bayonet, accoutrements and sixty rounds of ball cartridge. Weight of rifle, accoutrements and ammunition, 18 lbs.

All blue-jackets wear blue uniform, cap, leggings, knife and laniard, tin cup, spoon, canteen, haversack, and rolled blanket, containing shirt, stockings and towel.

All—officers and men—wear flannel underclothes, and a rigid inspection of shoes and leggings should be made before leaving the ship, and tobacco should be served out to every one.

The men of the infantry companies carry magazine rifle, bayonet, accoutrements and sixty rounds of ball cartridge. Weight of uniform, 9 lbs. 7 oz. —Weight of equipments, 18 lbs. 10 oz.

The men of the howitzer and gatling crews carry their ammunition pouches, a pistol and cartridges. Provision is made in the Ord. Ins. which permits some of the crew to carry rifles under certain circumstances, but the artillery officer should consider whether the advantages gained by having the rifles will outweigh the diminished celerity of the piece in consequence of the added weight to be carried by the men. Weight of pistol and sixty rounds, 6½ lbs.

Signal men carry each a signal kit with gear for signalling by day or night, and are armed with pistols. The signal officer and quartermaster carry glasses.

The pioneers are equipped with tools to whose use they are most accustomed: the most useful tools are, axes, picks and shovels, while saws, crow-bars and sledge-hammers are occasionally needed. The armorer who acts as sergeant of the pioneers, carries a bag containing tape measure, powder flask, gimlet and implements for repairing machine guns and small arms. Weight of axe, 5 lbs. 2 oz.,pick, 3 lbs. 6 oz., shovel, 4 lbs. 5 oz.

The field hospital corps carry a stretcher and the medicine chest, and each man in the hospital party should have a tourniquet and be instructed in its use. It will be found useful to have a small flag, the Geneva Cross, for example, to indicate the position of the hospital.

The paymaster's corps, being charged with the supply of provisions, will have to improvise some way of carrying what is needed beyond what is contained in the haversacks. Cooked rations for two days can be carried in haversacks. If the men are to be on shore for only a few hours, they should have one day's rations; if for one whole day,

they should have two days' rations and so on. The daily allowance of food is made on the following scale—

		lb.	oz.
	Bread	1	
	Meat	1	4
	Tea		1
or	Coffee		2
	Sugar		4
	Salt		½
		2 lbs.	10 or 12 oz.

making two days' rations weigh about 5 lbs. The reserve of provisions being apportioned by this scale can be easily calculated. The meat is best carried in the shape of canned beef, of which the cases weigh about 60 lbs. The supply of water is very important, particularly in hot climates, and, if water is not found the paymaster should land it in breakers as soon as possible after the landing has been effected. The ship's cook is attached to the paymaster's department and does what cooking is necessary for the command, assisted by the provision men. Kettles will be necessary in the proportion of one to each half company and howitzer crew. A set of scales and weights will be required.

The gunner's gang is charged with maintaining a supply of ammunition. The reserve ammunition can be best carried in limbers, which are supplied for all gatling guns; in default of these, other means of transport may be improvised by joining two field carriages. The ammunition for small arms is in boxes containing one thousand, and they weigh 118 pounds. One thousand rounds of pistol ammunition in a box weigh 72 pounds. Probably not much will be required for pistols, but for the rifles, if the firing is rapid, the expenditure in an action may be as high as eighty rounds a man, though it is not likely. It is desirable to have some means of supplying ammunition readily to any part of the command which may be in immediate need. The gatling limber (3-box) can carry about three thousand, five hundred rounds. For the other ammunition, the weights are—

1 box 3-in. shell	containing	10,	weighs 74 lbs.
1 box 3-in. shrapnel	"	10,	" 85 "
1 box 12-pdr. shell	"	9,	" 111½ "
1 box 12-pdr. shrapnel	"	9,	" 140½ "
1 box 12-pdr. canister	"	9,	" 113½ "

COMPANY DRILL. To teach anything properly it is necessary to be-

gin with the A B C, and we can have no successful drill unless the men are instructed carefully in the first principles and led on by gradual steps to perfection. The perfection in drill which is attempted, and sometimes reached, is neither necessary nor desirable with sailors: but on the other hand it is necessary that their training should fit them for the work they may have to do. This work, as far as connected with our subject, consists in operating on shore for two or three days at most, never far from their base, in expeditions against savage nations, sometimes, perhaps against civilized ones, always desultory in their nature, occurring rarely, and generally involving some hard fighting. The daily habits of the sailor develope the qualities of self reliance, readiness and fertility of resource, while his mode of life makes danger habitual. These are the very qualities which are needed, and all that remains is to encourage them, and by practical training to adapt them to the end in view. The first difficulty which presents itself is the sailor's dislike of the drill: this arises from the fact that from one end of the cruise to the other his small-arm drill has always been the same, with scarcely any variety; once a week he is given a musket and drilled at the manual for the greater part of the hour and made to march up and down the gangway in column of fours: sometimes other evolutions are attempted, but they are not those which are useful, and there is so little advance that he soon becomes disgusted and regards it as a necessary evil. This can be obviated by making the drill interesting and instructive, by relieving it of all unnecessary details, and teaching only what is practical and useful. The moment a man realizes that what is being taught him is of some use to him he begins to take an interest, and as long as that interest can be kept up he will learn quickly. The second difficulty is the short time that can be allowed for this especial drill. Sailors need to know so many things that it is not desirable to increase the time, for their other drills are quite as important. The time allowed for instruction in company drill will average one hour a week through the year. This seems very little, but a great deal can be done even in this time if every minute be utilized. To accomplish this the division officer must set before himself a definite standard to be attained, and this must depend upon the kind of work his men may have to do. Their work will not consist in executing dress parades or passing in review, but in operating, in large or small bodies, in a town or country unfamiliar to them, in the midst of a hostile people, in guarding consulates, in repressing insurrections, in bush fighting or perhaps, in storming fortified places. To prepare them for

these duties it is necessary to elaborate a system of instruction which may be changed from time to time as experience suggests, and to make it progressive, so that each time something new is learnt, and, little by little, the man gains in knowledge, and what he learns is learned thoroughly. Before the piece is put into a man's hand he must be taught carefully the principles of the direct step and of the double step, because the habit of marching properly will be of the greatest service when he has to go any distance on shore. The movements of the company which are needed are very few, but they must be so taught that no amount of confusion will throw them out. Wheeling by fours, forming line to either flank and to the front or rear, are all the movements that are necessary, and when these are thoroughly understood the rifle may be put into the man's hand, and he has passed from his A B C to solid work. In the manual of arms every officer wishes his men to be perfect, and more time is wasted in accomplishing this than in any other drill in the navy. Of what practical use is this perfection? The moment the men are landed and commence their work, either of fighting or of manœuvring over rough country, they carry their arms in the most comfortable way and will continue to do so until they have another dress parade on the quarter deck. If you tell a man with a musket to stand still, he will stand at an order: if you tell him to run, he will put it on his shoulder or carry it at a trail, though perhaps not exactly as laid down in the tactics; so that the movements of the manual, over which a great deal of time is spent, are those which the plainest common sense would dictate if they were not taught at all. The true test of efficiency in the manual should be proficiency in rifle practice, in the different kinds of fire, and in bayonet exercise.

To meet such tests the men must first be taught all the parts of the rifle and their uses, and to dismount and assemble it themselves; then the aiming and position drill, carefully in all the details loading and rapid firing with dummy cartridges, aiming at different elevations, with the use of the wind gauge, firing with blank cartridge singly and in volleys, and finally ball practice at known ranges, and judging distance: next a few movements of attack and defence with the bayonet, and the instruction in the manual will be completed. These are not all to be taught in a day, but they can be taught in a wonderfully short time, if it is done systematically and without useless repetitions. The next drill should be instruction in skirmishing. Formerly the skirmishers *prepared the way* for the attack of the main body; now the fighting is done by the skirmish line, and this kind of fighting makes a greater

demand for individual instruction. Each man must be taught to act independently, and yet with the others, and to exercise a certain amount of judgment. The next instruction should be in the duties required of out-posts, advanced guards, and working by small squads under petty officers. More care should be given to the teaching of the petty officers than is generally done, and they should be habituated to exercise command in their companies as readily as in their parts of the ship or in their boats; the sooner they are able to do a certain amount of drilling and instruction themselves, the sooner do they become valuable. But the most important fact to remember is that it is to thoroughness of company drill on the part of the divisional officers that success in shore operations must be due; therefore it is all important that their part of the work should be well done.

Battalion Drill. The movements of the battalion which we need to know are very few, and as a general rule the simplest are the best. Although at first sight it appears difficult to teach any movements of the battalion on board ship, the difficulty will be removed by having a skeleton drill, that is using all the officers and petty officers of the companies, and only four men, to represent a company. In this way those who need the drill can get it even in a confined space. The necessary movements for the march are forming column of fours, and reforming the line, close column of companies or divisions, the deployment of the close column and forming front into line faced to the front or rear. The column of fours is the only practicable order of march, and whenever the column has occasion to halt it should be formed up into close column of companies or divisions. In this formation, in case of sudden attack, it is ready for deployment, and there is no question about the time necessary to bring up the rear, or their condition when they arrive on the ground. Having mastered these evolutions the whole attention may be given to skirmishing. In the skirmish drill of the battalion I do not think it advisable to follow strictly the principles laid down in our tactical book, because the experience in the late wars in Europe shows that other principles have been adopted for all the great armies, and I have used for some time, for skirmishing, a drill which I have made by taking the principles laid down in the English, French and German drill books, and adapting them closely to Upton's Tactics, and this I will now explain with as little detail as possible. The battalion of four companies is deployed for attack as follows. The battalion is formed in two lines with the first, second and third companies in the first line, and the fourth company in the second line as reserve. In

advancing to attack the battalion is divided into (1) fighting line, (2) supporting line, (3) main body, and (4) reserve. The movements of the fighting line are regulated by the battalion commander, and it is important to establish a perfect system of linkmen between himself and the company commanders on the fighting line, and the officers with the main body and reserve, so that his orders may be passed rapidly without necessitating the use of drum or bugle. The duty of the fighting line is to keep up a fire on the enemy whenever it is effective and until the final rush is made. The duty of the supporting line is to reënforce the fighting line, when needed, to make up its losses, to supply ammunition, so that its fire may not slacken. The duty of the main body is to follow up the movements of the fighting line and, with it, to finally force the enemy's position. The reserve is to be used as circumstances may require. The distances between the several parts of the battalion will depend upon circumstances. The fighting line being thrown forward so that it will be about one thousand yards from the enemy, the supporting line about two hundred yards in rear, and the main body about three hundred yards from the supports. Previous to the advance an objective point should be decided upon, and explicit instructions given to the company leaders. At a distance of about fifteen hundred yards from the enemy, the column should be deployed into line with intervals between the companies of half distance. The deployment of skirmishers commences by sending to the front a thin line, numbers one of front rank of each four, as a fighting line; and, as they advance, the skirmishers extend to the right and left. This is followed at the proper distance by the supporting line, numbers two and three of front rank of each four*, followed in turn by the main body. The fighting line must take advantage of any cover it can obtain, but must not diverge from the direct line. The supports and main body keep covered as much as possible. The company commanders accompany that part of their companies which is on the fighting line; the chief petty officers are with the supporting line and the junior company officers are with the main body. This arrangement leaves under the control of the company commander his fighting line and supports, and prevents the confusion which is likely to occur when one company is supported by another. Each company commander can judge if he is so strongly pressed as to need reënforcement, and can reënforce his own line from his own men. Thus the men are always under the con-

* The deployment is always by numbers.

trol of the officer to whose direction they are accustomed, and who knows them all personally. When firing begins it should be slow and careful so as not to waste ammunition. No firing is permitted while advancing, but at a given signal the fighting line will cease firing and advance with a rush for about thirty paces, when they lie down and commence firing again: this gives every man a chance to regulate his sight, and to fire from a rest. The supports and main body follow the movement, gradually diminishing their distances: the thin fighting line is pushed up as close as possible before it is reënforced; and this is done by sending up numbers from the supporting line who are replaced from the main body. On approaching the enemy's position the fighting line is strengthened until it has absorbed the main body, and the reserve is brought up into a supporting position: after this the firing is by alternate companies kneeling, by word of command, and the lines pushed up by companies, advancing with a rush successively, for short distances, under cover of the fire of the rest of the companies. A front attack should be a last resort; before this is attempted every means should be tried to turn one flank or the other. When ready to make the attack word is passed along to prepare to charge, when bayonets are fixed and the line advances at the double: when it has arrived within charging distance the bugles and drums sound the charge. From the moment when the double commences, the first line will appear to be in confusion, which becomes greater as they near the enemy's line. This is in a great measure unavoidable, but every attempt should be made to preserve the alignment to the last moment: and the reserve must be ready to reënforce any portion of the line. In advancing care should be taken to keep the flanks always protected, and this is done by extending the skirmishers on the right and left flanks and bending them back. In receiving an attack the skirmishers must be kept in front as long as possible, and when they are driven in the fire must be given deliberately. It is well to remember that the best way to meet a charge is with a counter charge.

It is quite as important to teach the principles of attack, as the movements which may precede the attack, and all the principles of this method of skirmishing can be taught on board ship. It is advisable to use powder in drilling as soon as the men reach a moderate degree of proficiency, particularly in drilling on shore: for officers and men become accustomed to receiving and transmitting orders in the midst of noise, and are not likely to be gallied by a considerable amount of confusion. The importance of this will be realized on the first drill

with powder, for men who are not in the habit of firing sometimes become extraordinarily excited, and lose their heads even when firing blank cartridges.

Artillery Drill. The same general principles of instruction should be applied to the howitzers as to the company. The only manoeuvres necessary for the howitzer on shore, are wheeling to the right, left, and about, going into battery, and moving by hand to the front or rear, and a very short time is necessary to obtain considerable proficiency in these. What is of vital importance however is to teach the men all about the charges, projectiles and fuzes, the service of the piece, the manipulation of the sight, and judging distance; so that each man will know the capabilities of his piece and be able to perform any duty at the piece. To make the drill successful it must be systematic, so that in a certain time every thing necessary shall have been taught. As soon as the instruction in working the piece both on shore and in the boat has been completed a series of exercises in target practice should be commenced, with all kinds of ammunition, from the boat and on shore if it be possible. The men should be taught that their weapon is the piece, that their safety in action will depend upon the way they work their piece, and that it only needs judgment and coolness to make it a powerful weapon. One point to which the officer of the piece must especially devote himself is to having as large a supply of ammunition as possible, and every device by which he can increase it will be of the greatest value to him.

Combined Drill. To prepare the men for this drill it is advisable that the old fashioned battalion drill be given up entirely on board ship, and that the drill of the landing party be substituted for it. Whether the ship be large or small it should have a properly organized landing party, and whenever time can be given, it should be drilled as such, care being taken to have all the details perfect in every drill: by doing so men become habituated to their several duties and are all the more ready to perform them when the occasion arrives. If the force consists of only one company and one gun it is better to manoeuvre them together habitually and they will thus get the idea of mutual support. It is of great assistance in any drill to notify beforehand all the officers, who are to take part in it, of every manoeuvre that is to be performed; in this way every one is prepared and the manoeuvres will be executed properly, and no time will be lost in correcting mistakes. In the same way before entering upon any undertaking of a hostile nature it is advisable to give to each officer any information that may be useful, and

particularly to let each one understand thoroughly what work he will have to do and what is his position in the boats and on shore with reference to the others. A certain amount of practice in manoeuvring the boats is necessary before a landing takes place and it will be found of great assistance to exercise the boats, when armed and equipped for landing, in the evolutions likely to precede a landing, the howitzer boats being placed on the flanks or in the center as circumstances demand. The boats carrying guns when fully equipped, are so much heavier than the others that they are worked with less rapidity and ease, and are likely to throw out all the rest of the boats; this may be avoided by lashing the heavy boats on each side of the steamers and keeping them there until ready to disembark, and it will then be found that they are always in place, or easily transferred to any point of attack, while, at the same time, their crews are fresh for the work on shore, which is generally very laborious. In forming for landing it is better to form in two or three lines, because the boats in line take up so much more room than their crews do when formed on shore, that too much time would be lost in closing the intervals, and moreover the second line following the first is ready to support. In landing the naval brigade, whether it meets with opposition or not, an advanced force of infantry must be landed first, to scour the country near the beach, and to form a line of outposts to prevent surprise. Next would come the infantry of the first line and the artillery followed by the second line and so on. The artillery should be placed in as favorable a position as possible immediately after being landed, and be ready to open fire. If the landing is opposed, the artillery is used to clear the beach for the infantry, and the artiillery itself should not be landed until the infantry has secured a good footing. When all the forces have been landed, the lines are formed, skirmishers thrown out and the work commences. In the English service an officer is appointed who is styled the Beach Master, a title which we might very well adopt, who is charged with the care of the boats left behind and with keeping up communication with the ships and preparing a depot for ammunition, provisions, water, hospital stores etc. His first duty is to have the boats ready for the reëmbarkation at any moment, and to do this he must be acquainted with the rise and fall of the tide, the currents etc. He should have signal men for communicating with the ships and the forces, and some men to defend his depot. After landing the truth of what I have said about evolutions will soon be evident and officers will realize that the drill book is not tactics, but the true tactician is the one

who is the quickest to see the weak points in his enemy's dispositions, to turn every chance to his own good, to foresee accidents and to provide for them, to save his men as much as possible but at the right moment ready to run any necessary risk, while the governing principle should be to concentrate as many as possible of his own men on the smallest possible number of the enemy.

I do not intend to touch upon field fortification at all; the necessary knowledge is contained in books which are familiar to us and at the command of every one, but the men when on shore should be instructed in intrenching themselves and taught to do it whenever they are under fire. A few minutes will suffice to give a man a small amount of cover in moderate soil, and if men are to remain in any position for any length of time, they should understand how to make a small shelter trench with only their bayonets and tin cups.

I have shown you this evening how, without failing in their duty as sailors, our men have in the past history of the navy done valuable service on shore. We have seen them at Bladensburg and at the head of the Chesapeake, when the militia gave way and they had to stand the brunt of the attacks and secured the safety of Baltimore; we have seen them breaking up nests of pirates in the West Indies, and punishing the Malays in the East Indies; we have followed them in the Mexican war when Stockton in the north with his naval brigade conquered a large territory; when Shubrick in the south captured Mazatlan, and Rowan, Lavallette, Craven and Selfridge kept the west coast in a blaze while Perry occupied and laid under contribution the east coast from the Rio Grande to Vera Cruz: we have been stirred to sympathy for the gallent fellows who fell at Fort Fisher where their defeat contributed to the victory of their brothers in the Army, and since the war we know of the disastrous affair at Formosa, of our men being landed in different parts of the world to protect our own people and the foreign residents, and of the successful expedition to Corea to punish an insult to our flag. In general it will be noticed (1) that in a war like that with Mexico, all the naval operations involve landing parties, and (2) that in time of peace it is principally by means of landing parties that the Navy acts, when it is called upon to act at all. Landings are always liable to take place (1) when we have treaty guarantees to execute as at Panama, (2) in revolutionary countries, where Americans require protection as at Honolulu and Montevideo, (3) in uncivilized countries where attacks may be made on shipwrecked crews, as Formosa and Corea, and (4) at distant points not readily accessible to

troops, as the coast of Mexico or Central America. To ignore the utility of this work is to neglect one great source of usefulness in a squadron which can appear unexpectedly at different points on an enemy's coast and harass him very materially by obliging him to keep strong garrisons at all points.

With such a record in the past it behooves us to maintain it in the present and in the future. We have seen how with limited drill and inferior arms our predecessors of glorious memory acquitted themselves. But modes of warfare have changed entirely in fifty years and even the savage of the present day is no mean enemy, while our men are likely to be pitted against disciplined troops. Shall we then decline to give battle for the honor of our flag or for the protection of our citizens because our enemies may be well armed and drilled, or because we should be off our natural element? Every officer and man in the service would answer—No. The question is not whether the seamen are primarily intended for another kind of service: everybody agrees that the primary purpose of seamen is to man ships and to fight at sea. The question is rather in what way we can bring the most effective force against an enemy whose positions on land we are attacking. If we have a squadron with a thousand men on board, and all the operations have been concluded of which the squadron, as a squadron, is capable, are we to allow our thousand men to remain on board idle while the troops are engaged on shore, simply because their vocation is to fight on the water? It is not proposed to strip the ships and to turn their crews over to the army; but there may be times, as I have shown, when the service required is that combined land and water service for which the seamen are peculiarly fitted. Having the material for this purpose, shall it not be made use of? And if it is to be made use of, it must be prepared by thorough training. With this end in view I have endeavored to present a system of organization and instruction which will render our blue-jackets an efficient force when they are landed.

At the same time I hope I shall not be misunderstood as being in favor of turning the navy into a military machine. Far from it. We must first of all train up a body of men to fight on the sea: but so long as there exists a possibility of our having to fight on shore, let us prepare for that exigency also. By making our drills practical and instructive we shall find that our men learn readily what is needed, and we know that the true sailor possesses a gallantry which only needs to be properly directed to enable him to overcome any obstacles.

The CHAIRMAN: I desire on the part of the meeting to offer thanks to Lieut. Soley for the paper he has just read.

It seems to me that we would make more progress in this matter were we to draw more marked distinctions between Tactics, Grand tactics, and Logistics, and teach them with this distinction in view. The simple tactics, the part to be learned by the *man*, should be taught not as an *end*, as it usually is, but as a *preparation* for drill. It should be boiled down to its simplest form, taught thoroughly once and for all. Then we can proceed to the *real* leading drills, which are important matters for the officer. Here the man merely puts in practice what he has learned; thus giving point to his knowledge and adding interest and, what is more important, experience.

I think if five or six imaginary operations could be worked out in minute detail, selecting for the scene Hampton roads, Newport, and one or two other places where the ships could assemble for landing drills, prepared like a theatrical play, illustrated with large scale colored maps (8 inches to the mile) it would be of enormous benefit. It would be simply necessary to issue an order for operation No. — and make the details for the several roles fill out the cast, so to speak. All the experience of real war would be obtained except in the element of danger. One or two should be for the night.

I believe the true reason of the confusion frequently met with in landing blue jackets is a slovenliness in primary instruction, a slovenliness of which we officers ourselves are not wholly guiltless, as evidenced in the teaching of such movements as *two's right about*, movements utterly unauthorized in the tactics. Company drill is really extremely simple; but it is amazing how few blue jackets know even how to halt. The manual of arms is another matter and is really of small importance. Shooting and manœuvering are the two chief things required.

I do not exactly see the objection to the trumpet. It can readily be learned in a month and is extremely useful in handling squadrons of boats as well as howitzers and skirmishers.

Lieut. Com'r. CHADWICK— I noticed, in a visit which I paid on board the Bellerophon, at Barbadoes, some two years since, kits at hand ready for landing. These were made up of the usual articles of clothing carried by landing parties, and were neatly packed in a canvas cover which could be strapped on as a knapsack. They were made up of course from the men's own clothing. The kits were kept overhead in the men's quarters. Thus nothing but the blanket needed to be added, and they were ready at once. To show that such a thing is necessary, at times, I shall cite the case of the sudden sending off at night of 200 men, from the receiving ship at Norfolk, to Washington, during the riots of 1877, where great confusion ensued from the getting out of clothing etc., many men going without any change whatever. Leggings should be made a part of the uniform, and obligatory.

I am thoroughly in accord with all the ideas expressed by Lieut. Soley, and especially deprecate, with him, the adherence by so many to the idea that the knowledge by the sailor of the use of the musket and of infantry tactics is useless. I regard it as necessary in a very high degree, and think that any seaman is a better man and a better sailor even for this added knowledge. It has been my observation that the men who have shown most proficiency in such things on board ship have at the same time been our best men in seamanship duties. The sphere of a sailor's duties is not so large but that it may contain the knowledge of how to shoot with a small gun as well as with a big one.

Lieut. HANFORD. I would like to ask the lecturer how the paymaster is to transport the provisions etc. and where the men are to get their haversacks and canteens?

Lieut STOCKTON. The lecturer gives canteens and haversacks as part of the equipment of the men of the landing party, and with these water and rations for forty eight hours can be carried by each individual. In point of fact there are no canteens or haversacks among the stores of the ship for

the men, that is for the blue jacket. There is no doubt that by a liberal expenditure of canvas, haversacks can be made, but it is a question whether, with the limited supply of tin ware on board, canteens can be improvised for the whole landing force. It would take a long time to make these articles with the resources of a single ship.

Personally I quite agree with the author of the paper just read in regard to the waste of time in the manual of arms and in the endeavor to get the manipulation of the rifles and the movements generally mechanically perfect; besides being a waste of time, it stifles the individuality of the sailor: and sacrifices celerity and freedom of movements to an unnecessary unity in detail. A writer lately pronounced the uniformity of detail in handling the guns and the mechanically correct manœuvres in marching, wheeling, and alignment as the coxcombry of the profession, and I think it should be relegated to the militia and to avenue parades. In time of actual war this vanishes into thin air and is not of the business of war. I do not wish to say that, given a body of men, to act as infantry, they should be kept in a chaotic state; but the movements taught should be restricted to simply the necessary ones, to those that will conform, as much as possible, to the characteristics that should be found in sailors.

The skirmish drill is well adapted to seamen and should be taught the men more frequently than is now the custom. I hope Lieut. Soley's proposed formation of skirmishers will be thoroughly tested and criticised by military experts.

Master LYETH. In reply to Lieut. Hanford's inquiry as to the immediate wants of sailors on landing, especially in hot climates, for water, I would state that I took part in several landing parties for exercise conducted by Lieut. Soley, the summer of 1877, in Smyrna; the weather was very warm and a sufficient supply was with some difficulty kept up by the provision men of each company carrying water to their companies in mess kettles.

Lieut. J. W. MILLER. The organization of the Naval Brigade which the lecturer has given us to-night I have seen tested practically, both at Annapolis and by two ships of the fleet of which Mr. Soley was flag lieutenant. Although the exercises which have been conducted were necessarily on a peace basis, and the operations on shore bloodless, still all possible contingencies of actual warfare were provided for, and the majority of the details elaborated in the paper just read, were carried out in the most conscientious manner. One point upon which the lecturer dwells deserves the most earnest consideration, and that is the necessity of frequent naval brigade drills on shore. The vessels of our squadrons are so often separated that such drills are rare. Every effort should be made to bring the ships together. Granted that a few vessels may be assembled at some future date, every watch officer in the service should begin to prepare his division for a combined drill, and begin too at the A B C of tactics. Mr. Soley rightly says that a great deal of the so called "infantry" taught on board ship is a waste of time. When I first had a division my ambition was to make the men proficient in the manual, and at least three months were thrown away in drilling "by the numbers". Moreover, like most young graduates, I had the tendency to give too much time to explanation, and too little to execution. The short routine exercises should not be used up with talk. A man-of-wars-man learns much more readily by a simple repetition of an order than from long descriptions to which he is not listening; while the lazy landsmen are nothing loath to let the officer use his voice, while they stand at an "order" or comfortable "right-shoulder." Explanatory exercises should never, and never can, be combined with quick, spirited drills.

The next and most important point of all is to teach the men to load and fire properly. This is rarely accomplished in a satisfactory manner on board ship. The quarterly allowance of small arm ammunition is usually expended at a target swung from the fore-yard arm; the men thus get in the habit of firing high and the range is too short. There is no reason why

Wingate's aiming drill, with the assistance of sand bags, should not be employed at first, to be followed by the armory target practice used with so much success by the militia. The Lowell cartridge company is now manufacturing a strong reloading shell, to contain eight grains of powder and a bullet, which will carry two hundred yards. A large folding target of boiler plate could be used in connection with this cartridge: the men to fire from aft; the target to be placed on the forecastle; the folds to form side screens, and a protection for the deck.

The proficiency of the divisions and companies is of the last importance and it behooves the watch officer to attend to all the minutiae, without which the larger operations on shore will prove failures.

I entirely agree with the lecturer that blank cartridges are not enough used on shore drills. All of us know the great difference that exists at great-gun drill between the actual general quarters with and without powder. Every detail may be seemingly perfect in the latter: yet when the men have to handle real charges for the first time, noise and confusion are often the result. Such confusion is tenfold greater when we pass from the ordinary battalion parades to the action of the skirmish line—even with blank cartridges. In case of a battle, the brigade which has been accustomed to the use of powder will undoubtedly stand fire better, while the linkmen and aides will have had much experience in passing the word from the outer line, and carrying orders quickly and quietly. Those gentlemen who have been to the "farm drills" at the Naval Academy, will appreciate the force of the foregoing remarks.

In conclusion, I would like to ask the lecturer whether, in his opinion, the skids formerly provided for landing howitzers, and still in use by some ships, are as serviceable as the single shifting spars coming into service. My experience with the latter leads me to think them far superior to the cumbersome skids advocated by so many officers.

Lieut. SOLEY: It is a matter of gratification to me to find that the ideas which I have put forward have been so well received. I am sure that all thinking men must see, sooner or later, that every thing must be eliminated from our drills that is not necessary as a preparation for war, and at the same time that nothing must be omitted which would tend to that end. My experience has taught me that the only way to have a successful drill is to take plenty of time in preparing the details; the more thoroughly the details are prepared the more will all concerned be ready for actual service, and in our squadrons we want to get as ready as possible in the shortest possible time. A great deal might be done on board the receiving ships, where our newly enlisted men are trained, by having an organized landing party; individual officers may work here and there, and work hard, but they have to encounter, on one hand, prejudice, which is disheartening, and, on the other, apathy, which is ten fold more aggravating. In such cases arguments avail nothing. If arguments did any good they might be taken beyond our own naval history, and shown how almost every navy in the world in the last ten years has used its naval brigade more than any other part of its naval force. In the Franco-Prussian war a whole division was landed from the French fleet and sent, under a Vice Admiral, to garrison the forts around Paris. In the Ashantee and Zulu campaigns the English landed their men and they were valuable coöperators with the army. When the English fleet went into the sea of Marmora, they immediately made preparations to land men to hold the lines of Bulair. Does any one think that this could have been done without complete preparation?

After the preparation of drill should come the preparation of equipment. Mr. Hanford has asked where we would get the canteens and haversacks with which the men are to be supplied. Of course, we have none furnished to our ships, and if we had to improvise them from the ship's stores a man would be at his wit's end: haversacks might be made, while the canteens

would give more trouble. I think that if any one of us were going on an expedition he would not hesitate to buy them if he could, but I think that enough of each should be supplied for the landing party of each ship. With regard to the transport of provisions some means must be improvised which will depend upon circumstances: in some cases the native population may be impressed into the service; in civilized countries means of carriage will be easily found; but it is proposed that each man shall carry enough for two days: more is not likely to be required.

With regard to the use of the trumpet I do not think it is very useful except for very simple signals, such as forward, halt, charge, commence or cease firing, and the like. For extended movements aids and wig wag signals are the best.

I think that the skids which are furnished for the launches are worse than useless, for they are only lumber in the boat, and weight which does no good. We are not likely to have in a boat any gun which is too heavy to be handled by a shifting spar. The tactical movements which a sailor needs to know are few in number: the officer needs to know the principles of tactics, and he has plenty of opportunities to learn them if he chooses: and most officers will have sufficient pride in their profession to learn them if they will only reflect that they are more likely to be called upon to fight on shore than on the sea.

PROFESSIONAL NOTES.

These Articles have not been read before the Institute, but are inserted by direction of the Executive Committee.

Details concerning the capture of the Huascar. Questions asked by the officers of the U. S. S. Pensacola, and answered by a Lieutenant of the Chilian Navy who served on board the Almirante Cochrane in her fight with the Huascar off Angamos October 8, 1879.

Question 1. What is your opinion of the way the Huascar was fought? first as to the handling of the ship, and second as to the serving and pointing of the guns?

Answer. I consider that the Huascar, during action, was very poorly handled; from beginning to end she did nothing but try to escape, notwithstanding that those on board of her saw that our ship was steaming nearly a knot more than she. Captain La Torre steered straight for her, in order not only to shorten the distance but to bring her to the condition you mention in the second question. In my opinion, and in that of our captain, she ought to have preferred steering west, and finally given us her ram, but never her stern. The same shot which killed Captain Grau disabled part of the rudder chains leading to the fighting wheel; from that moment recourse was had to relieving tackles aft, and it is worth noticing that no officer appears to have been attending to these. No executive officer was killed or wounded outside of the fighting turret; no communication was established through voice tubes, telegraphs, et cetera, to after part of the ship: steering was carried on by word of command only—the worst possible thing in action, the words *babor* (port) and *estribor* (starboard) being so similar that a mistake is very easy.

The serving of the Huascar's guns, judging by the amount of firing, was not bad—especially during the first half hour. As regards pointing, I can only say it was wretched—in fact could not have been worse.

QUESTION 2. Do you not think that, when you got on the Huascar's quarter, you had her not only in a very disadvantageous position to herself but in a position from which she could not easily extricate herself?

ANSWER. I quite agree with you—after we got close to her.

QUESTION 3. Was your speed uniform throughout the action? Was the Huascar's? What were they?

ANSWER. Our speed was uniform during action; so was the Huascars: eleven to eleven and a half, and ten and a half to eleven knots respectively. No hitch of any sort occurred in machinery or boilers on board of either ship. According to our chief engineer's statement our ship's speed might have been increased towards the end of the action, when she attained her highest pressure. The ship's bottom and boilers had lately been cleaned and overhauled. The Huascar had been four months out of dock—her bottom being rather foul.

QUESTION 4. What projectiles did you use? What fuzes? Captain Breese says that when he was on board the Cochrane last April, both you and your brother spoke very highly of some new fuze you had just received; what were these and did you use them?

ANSWER. We used Palliser shell, provided with gas-checks; no cored Palliser shot were fired, although a sufficient number are kept loaded in battery. Two of the gas-checks were found in the captain's cabin after piercing the plating of the stern. Quill friction tubes of not very good quality were only employed. If I remember well, Captain Breese must refer to an ebonite electric tube we received last year, and which I am sorry was not employed for want of a sufficient number of firing keys. I consider that there is nothing safer than an ebonite tube and firing key.

QUESTION 5. What do you believe was the effect of the shots, which penetrated the Huascar's turret, upon the men inside? Were many of her wounded hurt by splinters from the backing?

ANSWER. We do not think that many were wounded by splinters from backing, but by some occasioned by shell after piercing the ship's side.

QUESTION 6. Was there any particular reason why you did not attempt an electric broadside, or was that method of firing distrusted before the action began?

ANSWER. An electric broadside was not distrusted, but considered unnecessary. On preparing for ramming, our guns are fired independently and in succession; the two bow guns are laid for three hundred yards right ahead, and the others on the beam close along side: these

last cannot converge inside of two hundred yards. On passing alongside the Huascar, two guns on the side were only ready in time; the bow gun was fired as explained in my letter to Lieut. Meigs, and the other one missed fire from a bad tube.

QUESTION 7. Did the Captain find any difficulty in handling the ship with the fighting wheel? Was the communication and reply easy?

ANSWER. The fighting wheel was not used in our ship during action. As firing whilst under full speed has been often tried, I do not think that any difficulty would be experienced in handling ship with this wheel. The shifting from one wheel to the other is done in less than two minutes.

QUESTION 8. When the Huascar was taken possession of, was she boarded by a large party? What was her condition, as found by this party? What steps ought an officer commanding such a party to take to prevent the destruction of his prize? Was her crew demoralized, or were they still under control?

ANSWER. The Huascar was boarded, taken possession of, fires extinguished, two sentries posted, engine-room valves and water-tight compartments, (between engine and boiler room), closed by six men (riggers), two line officers and one engineer. Not a man was allowed to leave our battery or lower deck. On getting alongside the monitor, our boat was almost swamped by a crowd of sailors and soldiers carrying large bundles of clothes. I was helped over the side by the paymaster, midshipmen and other people, being received, cap in hand, by Lieutenant Gareson. The crew was in a dreadful state of excitement and fear, imploring our men not to kill them. The lining in the captain's turret had caught fire, and fallen through into the magazine flat; on this account, the Peruvian officers and men thought that the ship would blow up. The officers had no control whatever over the crew; the dead were lying about the decks—the captain's state-room being a heap of mangled corpses; the ship undoubtedly was very much knocked about. A sentry was immediately posted at engine-room and magazine door, and some of the prisoners made to help in extinguishing the fire. The engineer and firemen closed the water-tight door and valves, and put donkey in motion; the engineer reported engine, boiler and magazine safe ten minutes after we boarded her,—Rifles, in perfect working condition and about a hundred in number, were found untouched in their respective racks below. There were three feet of water on engine-room floor: bunkers full of midshipmen: wing-passages obstructed by the civil branch. The flag was lowered twice, and the Huascar's engines

were stopped after being hailed by Captain La Torre to do so. We ran alongside, and lowered our only boat not inboard at the time.

As regards steps to be taken by an officer boarding a prize, I really can suggest nothing (except closing water-tight doors), for it is my strong belief that a ship can easily be made to sink despite every effort of those who board her as a prize.

QUESTIONS ASKED BY LIEUTENANT J. F. MEIGS, U. S. N.

QUESTION 1. What is the light thrown on the relative value of broadside and bow fire by the fight off Angamos?

ANSWER. We are unable to say much or even appreciate the relative value of bow and broadside firing, as we always fought the Huascar on the chase; we only fired with our two starboard foremost guns, the angle of training of which you are well acquainted with. A form of battery like the Cochrane's presents great advantages in a case like ours.

QUESTION 2. How many shots did the Cochrane fire with her bow gun, with the centre gun, with the after gun?

ANSWER.

With	the	starboard	bow	gun, 20 rounds.
"	"	port	"	" none.
"	"	starboard	centre,	" 16 rounds.
"	"	port	"	" 1 round.
"	"	starboard	after,	" none.
"	"	port	"	" 1 round.

QUESTION 3. Did the Captain determine to run close to the Huascar at first, in defiance of any risk he might run in approaching?

ANSWER. The Captain determined not to open fire until at two thousand metres range, this being the range at which our guns can penetrate an armor similar to the Huascar's; besides he desired to destroy the enemy's ship at all hazards. The Huascar opened fire at three thousand and four hundred metres.

QUESTION 4. Was all firing by guns, singly?

ANSWER. The firing was carried on independently, rectifying the distance after every round.

QUESTION 5. Why was it the Huascar was not damaged by plunging fire, when you were so near her, and why did you not ram?

ANSWER. We were close to the Huascar on two occasions when ramming was tried at nearly right angles; we missed, and passed about five yards astern of her; our bow gun, trained right ahead, was fired at two hundred yards, and the centre one, trained abeam, with three

degrees depression, missed fire the first time and was being reloaded on the second. Plunging fire and ramming therefore never took place. One of the above bow shots hit the monitor's turret, and she immediately changed her course.

QUESTION 6. Was the smoke from guns and smoke stacks a serious impediment at any time, to handling the ship? If it was, please state the positions of ships, and the circumstances of wind and weather when it was so.

ANSWER. Neither the smoke from the funnel nor the smoke caused by the firing of our guns prevented the good management of the ship. We used smokeless coal, and steaming ahead continually at almost full speed prevented any great accumulation of smoke. At the most the battery was dark for about twenty seconds, our two fighting guns having been fired almost simultaneously. The weather was fine and clear with no wind; ship rolling quietly to an extreme (with her head east) of five degrees.

QUESTION 7. When in close action how long did it take to serve the 9-inch guns? Please state the distance.

ANSWER. Our men have had a good amount of training and loaded their guns in no time, i. e., thirty to forty seconds. Firing became sometimes difficult on account of the ever changing position of the enemy. Our first shot struck at one thousand seven hundred yards. Most of the firing was done at eight hundred to five hundred yards. You can take two minutes as an extreme limit of the time taken to fire each gun.

QUESTION 8. How long had you been in action when you first thought the Huascar actually beaten?

ANSWER. The Huascar was considered lost or actually beaten before an hour's fighting, when her stern was about twenty degrees open towards starboard bow, and at five hundred metres distance. In this position, we had our strongest power and facility of management against the weaker part of the enemy. The nwe damaged her stearing-gear for the second time, and the arrival of the Blanco precipitated her surrender.

QUESTION 9. What was the effect on your armor of the Huascar's 10-inch shot?

ANSWER. The Huascar's 10-inch Palliser shell was fired at about six hundred yards and struck our 6-inch armor on an angle of incidence of thirty degrees It penetrated three inches, removed bolts, inner lining, and broke on a beam. It probably broke up.

QUESTION 10. What light has been thrown on the question of the value of small-arms and machine-guns?

ANSWER. Our machine guns and top riflemen were of great value to us. The Huascar's deck guns were deserted by their crews. It can be said that in a ship with guns mounted on an open deck it will become almost impossible to serve them under an enemy's fire at five hundred yards from mitrailleuses and top riflemen.

QUESTION 11. About how long had your guns' crews been in training, and about how many practice shots had each gun-captain fired.

ANSWER. Our guns' crews have been in almost constant training for nearly fourteen months. It is difficult to state the number of practice shots that each gun-captain had fired. In peace time our ships are supposed to get firing practice twice a year; notwithstanding our men have had many opportunities of practising whilst cruising along the enemy's coast.

Huascar. Showing Probable Direction of Shots.

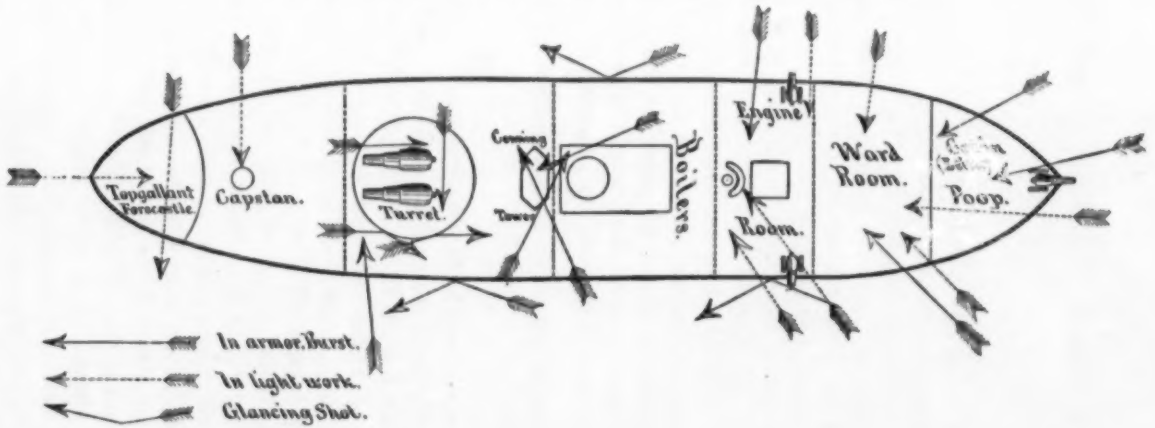


Photo-Electrotype Co. Boston.

THREE LETTERS CONCERNING A DISPUTED FACT.

The description of the battle of Mobile bay, given in the Life and Letters of Admiral D. G. Farragut, should have put an end to the long controversy respecting the "lashing to the mast." The discussion has, however, been again revived in several of the public journals, and articles have appeared to prove, on the one hand, that the admiral was not lashed at all to the Hartford's rigging, and, on the other, that he was securely bound to the futtock shrouds on going into the action. The following letters furnished the Institute by Loyall Farragut Esq., will, it it is trusted, forever settle the hitherto moot question, originally raised on the exhibition of a painting by Page, representing the position of the admiral during the passage of the forts. The first communication is from an old man-of-war's-man who served all through the war with Admiral Farragut, and reads as follows:—

U. S. Str. PHLOX, NAVAL ACADEMY, ANNAPOLIS, MD.
MARCH 2, 1880.

MR. LOYALL FARRAGUT,

Sir:—I see that you have written a life of your father, and that some of the newspapers say that the admiral was not lashed to the Hartford's rigging during the Mobile fight.* * * * Now, as I was chief quartermaster of the Hartford, and the man that lashed the admiral to the rigging, I ought to know something about it.

When we got close to the forts, I heard Mr. Kimberly, the executive officer, tell Mr. Watson, our flag lieutenant, to have a rope passed around the admiral. I was at the time busy with some signal flags for the monitors. Mr. Watson ordered me to go up in the port main rigging, where the admiral was, and put a rope around him. I cut off a fathom or two from a new lead line, which was lying on the deck; went up the ratlines to where the admiral was standing with opera glasses in his hands—just under the futtock shrouds, and made the forward end of the line fast. As I took the other end around the admiral he passed the remark that the rope was not necessary; but I went on and made the after end secure. I don't think he noticed the rope around him, as we were square abreast of fort Morgan; and it was pretty hot work. But when the ship got clear of the forts the

admiral had to cast the rope adrift before he could come down. Mr. Freeman * was all this time in the main-top, and possibly did not see me come up to lash the admiral. * * * * * *

Very Respectfully,

JOHN H. KNOWLES,

Quartermaster U. S. Str. Phlox, and late chief quartermaster of U. S. Flag-ship, Hartford.

I certify the above statement is true,

JAMES SMITH,

Late captain of the mizzen-top U. S. Str. Hartford.

The testimony of Commander J. C. Watson is equally positive, and shows that, though the admiral was in the mizzen rigging during the attack on the Tennessee, he was in the main rigging during the earlier part of the engagement. Commander Watson, writes as follows, to Mr. Meredith, who was on board the Hartford but having been between decks during the action requested an open letter on the subject of controversy.

MARE ISLAND, CAL., FEB'Y. 20, 1877.

MR. WILLIAM T. MEREDITH, CARE WILLIAM T. MEREDITH & CO.

37 William Street, New York City.

My dear Meredith:—I will gladly tell you how Admiral Farragut was lashed in the rigging of his flag-ship, the Hartford, during the "Bay Fight."

When the battle of Mobile bay began—with the firing of a shell from the monitor Tecumseh—shortly before seven o'clock, on the morning of August 5, 1864, Admiral Farragut, who you well know was as quick and active as the youngest lad on board, was standing in the port main rigging of the Hartford. As the smoke increased and obscured his view he went up the rigging, step by step, until he found himself partly above the futtock band and leaning against one of the futtock shrouds, where he remained until the fleet succeeded in entering the bay in the wake of his flag ship. While he was there Captain Drayton sent a quartermaster up with a hammock lashing, or piece of small rope, and a request to the admiral to allow it to be passed around him and secured to the rigging. After some little hesitation, or objection, Admiral Farragut took the rope and caught sev-

* Freeman was the pilot on board the Hartford, and has held, in several letters published by him, that the admiral was not lashed.

eral turns around his body and the shrouds, admitting that it was a sensible precaution. When the smoke cleared away, and there was no longer any reason for his being there, he came down, and was on the poop deck when the Tennessee followed up our fleet; and when the Hartford rammed the Tennessee he was standing in the port mizzen rigging, to which I secured him with a lashing passed with my own hands, to prevent his being thrown out of that rigging by the shock of the collision, or by a bullet wound, having first begged him not to stand there.

I was, you know, his flag lieutenant, and in direct communication with him during the battle, receiving orders from and conversing with him during the whole action. Lieutenant-commander A. R. Yates, acted as his aid in carrying orders. Hoping this is a satisfactory answer to your letter I remain your friend,

J. Crittenden Watson,
Commander U. S. N.

Finally the following extract from a letter—of which Mr. Farragut possesses the original—fully substantiates all the statements previously cited. It was recently discovered among the admiral's papers, and was evidently written in answer to a request, made by his wife, for particulars in regard to the affair.

Mobile Bay, Sept. 25, 1864.

* * * * I told you that Watson brought the rope to tie myself in the rigging; so he did, but Drayton sent one up by the quartermaster when I was up in the main rigging. I was so much interested in what was going on around me that I hardly noticed it, but took it mechanically and fastened it to the shrouds and around myself. * * * * *

D. G. Farragut.

To quote the words of one who was for many years associated with the admiral, both personally and officially—

"So far as the results of that great battle (Mobile bay) are concerned, the actual position of the heroic commander may be considered of little consequence; but as the truth of stirring incidents depends upon authenticated evidence it becomes sufficiently important to verify them by personal statements."

THE CHRONODEIK.

THE FOLLOWING DESCRIPTION OF THIS INSTRUMENT IS TAKEN FROM "THE SCIENCE OBSERVER," VOL. III., NO. 3.

"The instrument designated by the above title, is one which was devised to furnish a convenient means for finding the time within a second. It will be found to possess very great advantages in cheapness and simplicity over any instrument now in use, and is perfectly adapted to the wants of astronomical amateurs, watchmakers, surveyors, and exploring parties.

This instrument, the principle of which is entirely new, consists of a swinging bar, suspended, at its upper end, on a pivot, in such a way as to permit the bar to assume freely a vertical position without any torsional revolution. To the bar is affixed a small telescope, the object-glass near the bottom, the eye-lens at the top of the bar. Below the object-glass a frame is fixed to the bar, carrying a plane mirror swinging on a horizontal axis and provided with a clamp for fixing the mirror at any desired inclination. Below this is a metal bob. The whole instrument thus forms a pendulum, which is suspended inside a large tube, at the base of which are approximate leveling screws. A smaller tube at the top carries a dark-glass directly over the eye-lens of the enclosed telescope, without touching it. The cut shows the general external appearance of the instrument. The mirror, with the milled heads by which it is revolved and clamped, is seen through the apertures near the bottom of the enclosing tube.

From the above description of the construction it is evident that, if the instrument is turned so that the mirror is toward the sun, and the mirror is revolved on its horizontal axis until the rays from the sun are reflected directly up the telescope tube, an eye looking into the instrument from the top will see an image of the sun in the field of view. As the sun rises or falls in the heavens this image will rise or fall in the field of view, and its passage may be observed over a horizontal bar or wire placed in the common focus of the eye and object-glasses and so adjusted in direction that it represents a section of a small

circle in the heavens paralled to the horizon. This brief explanation will indicate the mode of using the instrument in getting the time by equal altitudes of the sun. For this purpose it possesses the most surprising facility. In cheapness and simplicity it has, of course, very greatly the advantage over the sextant—the use of which, with the artificial horizon, requires considerable skill, and involves much trouble and inconvenience—as well as over the small, portable Watchmaker's Transit, which requires careful mounting and adjustment, and even more skill and trouble than the sextant, in practical use. The instruments which have so far been constructed are very compact, and are portable in the coat pocket. They have object-glasses of six inches focus, the magnifying power being seven or eight diameters. The whole instrument is about one and three fourths inches in diameter, and stands about nine inches high. With instruments of this size and construction, the probable error of a single determination of the clock error with one instrument may be definitely stated to be within one second of time. Indeed, the actual results of an extended series of experiments with several instruments shows the probable error of a determination with one instrument to be somewhat less than this, or eight-tenths of a second. This degree of accuracy is probably sufficient for the purposes of most of those who will be likely to use the instrument, although it could easily be enhanced.

DIRECTIONS FOR MAKING AND REDUCING OBSERVATIONS WITH THE CHRONODEIK.

For Observations on Morning and Afternoon of the Same Day.

Set the instrument at any convenient time in the morning, not very near noon, so that the long aperture in front of the plane mirror faces the sun. Level by the foot-screws, so that the pendulum swings freely. Loosen the clamp-screws, (right hand milled head), and, looking into the telescope, turn the mirror by the left hand milled head until the sun appears in the field of view. Adjust and clamp the mirror so that the sun, when the pendulum hangs free and still, will be a little below the bar or wire in the field. Turn the instrument laterally, so that the sun is a little to the right of the centre of the field, and will in rising diagonally, by the diurnal motion, touch the wire near the centre. Observe the time, by watch, when the first limb or edge of the sun touches the wire, and also when this edge is completely across the wire. In general, this interval will be from twelve seconds to eighteen seconds. Record the mean of these times. About three

minutes after the 2d limb of the sun will pass the wire. Observe and record this in the same way as the first limb. Set the instrument carefully aside until a corresponding time after noon. Then set the instrument in the sun, level, and, *without disturbing the mirror clamp*, observe and record the passage of both limbs of the sun, as in the morning observation.

Reduction.—Take the mean of the times of the passage of the sun's first and second limb at the morning observation; also, the mean of the two times at the afternoon observation; then take the mean of these two means. The Chronometer time of local apparent noon is then found by the Equation of Equal Altitudes.

For Observations on Afternoon of one Day and on Morning of next Day.

In this case the only differences to be noted in the above directions are the following:— At the first or afternoon observation the mirror is to be adjusted and clamped, so that the sun will be a little *above* the wire.

It may not be out of place to add the following precautions:— Never observe *through a* window pane; even the best plate glass will distort the sun's image and vitiate the result. Arrange to observe the contacts of the sun with the wire as near the middle of the field as possible. Never disturb the mirror clamp between the two observations, as upon the fixity of this adjustment depends the precision of the result. If the sun is partially obscured by cloud, the observation can be often made by removing the cap containing the dark glass. The most rapid motion in altitude occurs, of course, when the sun is near the prime vertical, or directly east or west. It is scarcely necessary to say that in carrying the instrument about, between observations, it should be held in a slightly inclined position, so that the pendulum, resting against the side of the tube, cannot swing about and jar the mirror adjustment."

The *Chronodeik* appears to be a very ingenious illustration, or application, of well known laws of Optics and Gravitation. The thread placed in the common focus of the eye and object glasses should be parallel to the direction of the *circle of equal altitude* at its intersection with the vertical circle passing through the body observed. Practically, I presume, this is effected by fixing the thread parallel to the horizontal axis of the mirror; and this adjustment should be sufficient, provided the centre of the thread can be closely estimated. I think the instrument would be improved by using a second thread, perpendicular to and bisecting the first.

Wherever "circle of equal altitudes" occurs in this article, please read "horizon".

P. F. H.

The Chronodeik is restricted essentially to the approximate determination of time. The sextant may be used for the same purpose, and it seems unnecessary to argue that it is the best instrument in general use for the closely approximate determination of angular measurements.

The description of the Chronodeik says that "the actual results of an extended series of experiments with several instruments shows the probable error of a determination with one instrument to be about eight tenths of a second. This degree of accuracy is probably sufficient for the purposes of most of those who will be likely to use the instrument, although it could easily be enhanced."

When the sextant is used the same formula for reduction is employed. Professor Chauvenet remarks, "The chief source of error is in the observation itself. The most practised observers with the sextant cannot depend on the noted time of a *single* contact within 0ˢ 5, and hence the intervals between the successive chronometer times (which, if observations could be perfectly taken, would be sensibly equal) may differ 2ˢ. But the greatest probable error of the chronometer time of sun's or star's transit, from the mean of six such observations on each side of the meridian, is found to be not more than 0 2ˢ, provided the rate of the chronometer between the observations is uniform." (*Chauvenet's Lunar Distances and Equal Altitudes, page 72.*)

Using either instrument, errors due to changes in refraction may be almost wholly removed by computation. With the Chronodeik the observations are restricted to the transit over a single thread of the two limbs of the sun, while with the sextant the noted times of contact may be numerous. Stars may be employed with the latter instrument, but not with the former in its present construction.

The Chronodeik may be improved by enlarging it, and substituting a reticle for the single thread, with means of illuminating the reticle, but in its present form it is apparently inferior to the sextant. It is doubtful that the uses of the instrument would justify the improvements and increased expense.

P. F. Harrington.

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ADDITIONAL BRANCH, formed Oct., 1880.

Mare Island.

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CAPTAIN W. P. Mc CANN.

CORRESPONDING SECRETARY,

COMMANDER A. P. COOKE.

BOOKS RECEIVED.

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